PB80-213655

Summary of Occupational Radiation Exposure at Nuclear Power Plants 1969 through 1977

Office of Radiation Programs
Washington, DC

Aug 79

U.S. Department of Commerce
National Technical Information Service
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BIBLIOGRAPHIC DATA SHEET	1. Report No. ORP/TAD 79-11	2.	3. Recipient's Accession No. PB80 213655
4. Title and Subtitle Summary of Occupational Radiation Exposure at Nuclear Power Plants, 1969 through 1977			5. Report Date August 1979 6.
7. Author(s) Donald N. Rasch			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Office of Radiation Programs, EPA ANR-459 Washington, D.C. 20460			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Office of Radiation Programs, EPA ANR-459 Washington, D.C. 20460			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstracts

This report summarizes radiation exposures to workers at nuclear power plants as reported by the utilities or other owners for 1969-1977. The report provides an analysis of occupational exposures at light water reactors to determine if a correlation exists between such exposures and the additional waste management activities required due to the installation and operation of effluent control systems to meet more restrictive discharge limits and environmental standards.

17. Key Words and Document Analysis. 17a. Descriptors

Light water power reactors
Exposure
Radiation
Utility companies
Radioactive waste

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	UNCLASSIFIED	
	20. Security Class (This Page) UNCLASSIFIED	22. Price

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

United States
Environmental Protection
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Technical Note
ORP/TAD-79-11

PB80-213655

Radiation

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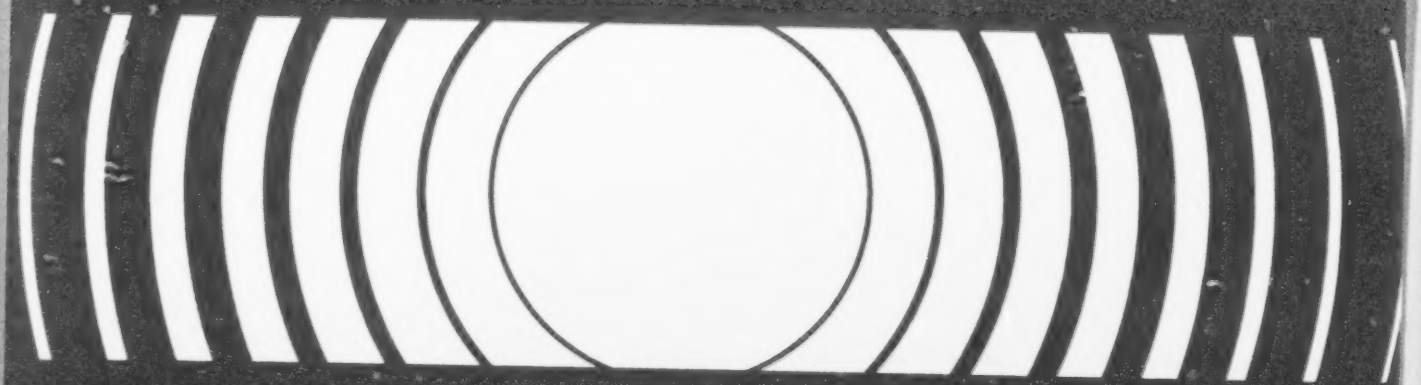

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Technical Note
ORP/TAD 79-11

SUMMARY OF OCCUPATIONAL RADIATION EXPOSURE AT NUCLEAR POWER PLANTS 1969 THROUGH 1977

by

Donald N. Rasch

August 1979

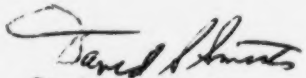
Office of Radiation Programs
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Foreward

The Office of Radiation Programs carries out a national program designed to evaluate the exposure of man to ionizing and non-ionizing radiation, and to promote development of controls necessary for protection of the public health and assurance of environmental quality.

Within the Office of Radiation Programs, the Technology Assessment Division has been conducting a program to assess the performance of effluent controls systems at light water reactors as compared to projections made of their performance and to evaluate the effects on occupational exposures and low-level waste volumes resulting from the addition of effluent control systems to reduce radioactivity discharges. The purpose of this report is to investigate possible correlations between radiation exposure to nuclear reactor personnel and the additional waste management required of effluent control systems to meet reduced effluent limits and environmental standards. The analysis was confined to an evaluation of the compiled data on occupational exposure to determine the possibility of an industry-wide relationship. As such, no attempt was made to identify specific causes of occupational exposure as, for example, the upgrading of plant safety systems to comply with more stringent seismic design criteria. Assessments of such specific sources of occupational exposures have been conducted by others.

Readers of this report are urged to inform us of any omissions or errors. Comments on the report are also welcome.



David S. Smith
Director
Technology Assessment Division
Office of Radiation Programs ANR-459

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Summary of Occupational Radiation Exposures at Nuclear Power Plants 1969 - 1977

I. INTRODUCTION

This report is a summary of radiation exposures to workers at nuclear power plants as reported by the utilities or other owners for the years 1969-1977. The purpose of this report is to provide an analysis of occupational exposures at light water reactors to determine if a correlation exists between such exposures and the additional waste management activities required due to the installation and operation of effluent control systems to meet more restrictive discharge limits and environmental standards. The approach used involved a compilation of the data and an assessment of the direction of the data over the years as presumably advanced effluent treatmemt systems were added. No attempt was made to determine what systems were added at specific plants or to evaluate the greater numbers of exposures or greater individual exposures at certain plants.

II. SUMMARY AND CONCLUSIONS

Sources for the data assessed in this report were the annual and semi-annual operating reports issued by licensees under the requirements of 10 CFR Part 20.407 of the Nuclear Regulatory

Commission (NRC). The data were compiled and analyzed as individual exposures, population exposures and cumulative percentages exceeding a given exposure level to aid in interpretation. The results are given in both tabular and graphical form.

The major conclusion of this assessment is that occupational exposure levels vary widely from plant to plant and in some cases from year to year. It appears this variation is due largely to unusual operating characteristics or situations at certain plants and perhaps to differences in management practices. This conclusion is further supported by the finding that wide variations exist in both individual exposure levels and in occupational collective exposures.

A second conclusion is that Boiling Water Reactors (BWRs) contribute more occupational collective exposure on a per plant basis than Pressurized Water Reactors (PWRs). This holds true for comparisons against both electrical output and plant rating. However, attempts to relate the greater exposures at BWRs with maintenance activities proved unsuccessful. It may well be that differences in plant design leads to inherently greater occupational exposures at BWRs.

Based on this analysis no definitive correlation can be found between the direction of occupational exposure data and the assumed introduction of advanced effluent treatment systems at light water

reactors. Although the data indicate an increasing direction on an occupational collective exposure per reactor basis, the variability in exposures from year to year at specific plants does not support a relationship between such exposures and the assumed introduction of advanced treatment systems. Since there is also a potential problem of interference from increased maintenance due to aging, it is concluded that if such a relationship exists it will only be found by a plant specific analysis approach.

III. Analysis of Reported Individual Occupational Exposures

The total number of exposed individuals from Boiling Water Reactors (BWRs) was compared graphicly to the total number of exposed individuals from Pressurized Water Reactors (PWRs). From the graphic pictures (Figures I and II), a similar breakdown was noticed for both the PWRs and the BWRs. In both cases a peak was observed in the range between 1.0 to 2.0 Rem. Through investigation, it was discovered that this is not a peak but an extention of the previous range. The previous range (0.0 to 1.0 Rem) was broken down to a set of smaller ranges. If these smaller ranges were all added together the graph would peak at 0.5 Rem and have a smooth downward curve through the ranges in which the fluctuation occurs.

The number of individuals exposed in each range increased each year. This is attributed to the increase in the number of plants. In 1977, though, there were no new BWRs that went critical, yet the number of individuals exposed continued to rise in each range. This could lead to the conclusion that the age of the plant contributes to the increase in the number of individuals exposed, for example, increased waste management activities may cause an increase in the number of exposures.

The data from BWRs and PWRs were combined for the total for all commercial LWRs, Figure III. This view of the LWRs gave nothing unusual; it was exactly what was expected, an increase in each range but identical to both the BWRs (Figure I) and the PWRs (Figure II).

For the years 1969 through 1972, the data for the number of individuals in the exposure ranges of "Not Measurable" to 1.0 Rem were combined into one range (0-1.0 Rem). The number of individuals in this range was broken up in order to provide an idea of the exposure distribution in the lower ranges; it also makes the data uniform from 1969 through 1977. This was done by percentage interpolation of the data for the years 1973 to 1977. This method gives the best picture of the range breakdown from the early years. Although the margin of error for this method is unknown, the yearly total of man-rem for each period

was the same as those calculated in earlier NRC reports. Therefore, the assumption is made that this method gives the best picture of the breakdown for the lower exposure ranges from 1969 through 1972.

IV. Analysis of Occupational Collective Exposures

The occupational collective exposures calculated for the years 1969 thru 1977 were obtained by using the mid-point of each exposure and multiplying by the number of individuals exposed in that range. Figure IV-A is a plot of the occupational collective exposures and indicates a uniform yearly increase. The rise in man-rem can be explained by the increasing number of reactors (Figure IV-B) each year. The fluctuation of the pattern was thought to result from maintenance on the reactors, refueling, and, in certain cases as is discussed below, the exposures due to unusual situations at a particular plant.

During the years 1976 and 1977, no new BWRs started up, but the collective dose increased by 37 percent or 7000 man-rem, as can be seen in Figure IV-A. It is believed that the aging of the plants contributes to the increase in man-rem, especially since maintenance operations are expected to increase as the reactors age.

An attempt was made to determine if the occupational collective dose could be related to maintenance activities, which presumably could be observed by comparing the electrical rating of the plants to actual power production. The comparison was made by plotting the occupational collective exposure annually against the electrical output (Figure V-A) and against the electrical rating (Figure VI-A). It can be seen from these graphs that the occupational collective exposure remained constant on an output basis (Figure V-A) for the 1974 to 1977 period whereas it had a steady increase on a rated capacity basis for this same period (Figure VI-A). On the basis of this analysis it was concluded that no significant increasing trend could be identified with maintenance or waste management activities. However, it can be postulated that occupational exposures should be decreasing on specific bases due to increased capacity of individual plants and the learning curve as experience is gained. If this is the case, the exposures per installed capacity and per output would be decreasing with time. The actual increases experienced as shown in Figures V-A and VI-A for 1974 to 1977 could then potentially be related to increased maintenance activities, especially for BWRs, or to increased waste management.

The most obvious finding of this analysis is that the BWRs contribute more to occupational collective exposure than the PWRs on a per plant basis. This holds true for comparisons against both

electrical output and plant rating. Since 1971 with only 1973 as an exception, occupational collective exposure at BWRs, on the specified bases, have exceeded the collective exposures at PWRs.

The sharp increase in 1973 for the PWR data as seen in both Figures V-A and VI-A was further assessed. The total man-rem for PWRs for 1973 was 9,379. Of this 56 percent or 5,262 man-rem was contributed by one plant, Indian Point 1, 2, and 3. Since the occupational collective exposure at Indian Point for 1972 and 1974 was 913 man-rem and 912 man-rem respectively, it was concluded that the anomalies in the data resulted from unique operations at this facility.

This anomaly with the PWR data suggested a similar situation might exist with the BWR data. The year 1977 was chosen for additional investigation because of the significant increase in exposure over the previous year while no additional plants were brought on line. The range of occupational collective exposures at 17 BWRs for 1977 was 225 to 3,532 man-rem with an average of about 1,300 man-rem. The data for the 18th plant, Millstone Point 1, were incomplete and not considered. The mean value for the 17 BWRs during 1977 was about 1,080 man-rem. While not as dramatic as the PWR data, these BWR data indicate that the situation at any given BWR plant can be expected to vary widely. It appears that fluctuations in the data for LWRs can be caused by plant specific operations.

V. Distribution of Cumulative Dose Percentages

Cumulative distribution plots are often helpful in assessing data when sufficient data are available to provide statistical meaningfulness. Since sufficient data were available in this analysis, the percentage of individuals that received less than the upper limit of a dose range was plotted per year for all light water reactors, PWRs and BWRs. From these plots (Figures XII to XXIII), an envelope (Figures VIII to XI) of the upper and lower limits of the percentage for all the years combined was developed. The development of the envelopes came from taking the highest and lowest percentage from the tables (Appendix C) for the combined years from 1969 to 1977. The upper limit indicates the most desirable case since it represents the largest percentage of individuals that receive less than or equal to a given dose. Conversely, the lower limit indicates the least desirable case since it represents the smallest percentage of individuals for the same dose. The envelopes give a picture of the dose distribution which can be used to estimate the potential effectiveness of reduced exposure limits to workers to compare a single plant to others of its type for self analysis.

The plots of the envelopes give a clear picture of the dose percentages. Comparing the BWRs to the PWRs (Figures IX and X or Figure VIII), PWRs had a wider band in the lower dose ranges (less than

1 rem), while in the intermediate dose range (1 to 5 rem) the PWRs remain to the right of the BWRs. This would indicate that the BWRs exposure percentages appear more desirable than the PWRs at the lower ranges. However, the BWRs have a wider band in the higher dose ranges (greater than 5 rem) and by using only the lower limit or boundary the PWRs would appear to have the more desirable percentages.

The data for 1977, however, indicate that there may be an increasing trend for the 1 to 5 rem exposure range at BWRs. In the exposure range from 4 to 5 rem were 428 individuals at BWRs as compared to 148 at PWRs for 1977. The data for 1976 in the 4 to 5 rem range were 267 at BWRs and 182 at PWRs. While it is not clear that there is a trend in these data, it appears to be departure from the nine year data composite as shown on Figures IX and X.

The envelope for all light water reactors combined is a narrow band that falls mainly between the BWR and the PWR envelopes (Figure XI or Figure VIII). Therefore, the total envelope gives the best picture in percentage terms to individual exposures in the commercial nuclear power plants today.

This was expected since:

$$P_b = \frac{NI}{TI}, \quad P_p = \frac{Na}{Ta}, \quad \text{and} \quad P_L = \frac{Ni + Na}{Ti + Ta}$$

where: P_b = percent of individual receiving less than dose D for the BWRs

P_p = percent of individual receiving less than dose D for the PWRs

P_L = percent of individual receiving less than dose D for the LWRs

N_i = Number of individual in all dose ranges up to and including dose range D for BWRs

N_a = Number of individual in all dose ranges up to and including dose range D for PWRs

T_a = Total number of individuals from all dose ranges for PWRs

T_i = Total number of individual from all dose ranges for BWRs

Dose D = upper limit of any dose range

From these formulas, P_L falls between P_p and P_b. Therefore, the upper limit of the envelope for the LWRs must fall between the upper limits of the BWR and PWR envelope. This holds true for the lower limits of the LWR envelope. This explains why the LWR envelope is narrower than both the BWR and PWR envelopes.

The number of individuals receiving exposures above 5 rem for the 1977 data was 93 for PWRs and 175 for BWRs. Almost all of these exposures for PWRs occurred at two plants: Surry which had 64 individuals and Zion which had 19 individuals above the 5 rem level. The BWR data followed the same trend with three plants contributing most of the exposures above 5 rem; Pilgrim had 112, Nine Mile Point had 20, and Oyster Creek had 13 individuals.

The 1976 data for PWRs included 150 exposures above 5 rem: 72 individuals at Surry and 67 individuals at Indian Point. BWR data for 1976 totaled 143 exposures above the 5 rem: level including 83 individuals at Pilgrim and 34 at Quad Cities. These data tend to confirm the conclusion that many of the higher exposures appear to be the result of unusual operations at specific plants.

VI Further Readings

U.S. Nuclear Regulatory Commission Sixth Annual Report of the Operation of the U.S. Atomic Energy Commission's Centralized Ionizing Radiation Exposure Records and Reports System - by Ms. Barbara Brooks

U.S. Nuclear Regulatory Commission NUREG-0322 Ninth Annual Occupational Radiation Exposure Report. 1976 - by Ms. Barbara Brooks

U.S. Nuclear Regulatory Commission NREG-0323 Occupational Radiation Exposure at Light Water Cooled Power Reactors 1976 - by Ms. Linda Johnson

Atomic Industrial Forum, Inc. (AIF) - Compilation and Analysis of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants

Individual plant data for 1969 through 1977 is available upon request by writing to:

David S. Smith
Director, Technology Assessment Division
Office of Radiation Programs (ANR-459)
U.S. Environmental Protection Agency
401 M St., S.W.
Washington, D.C. 20460

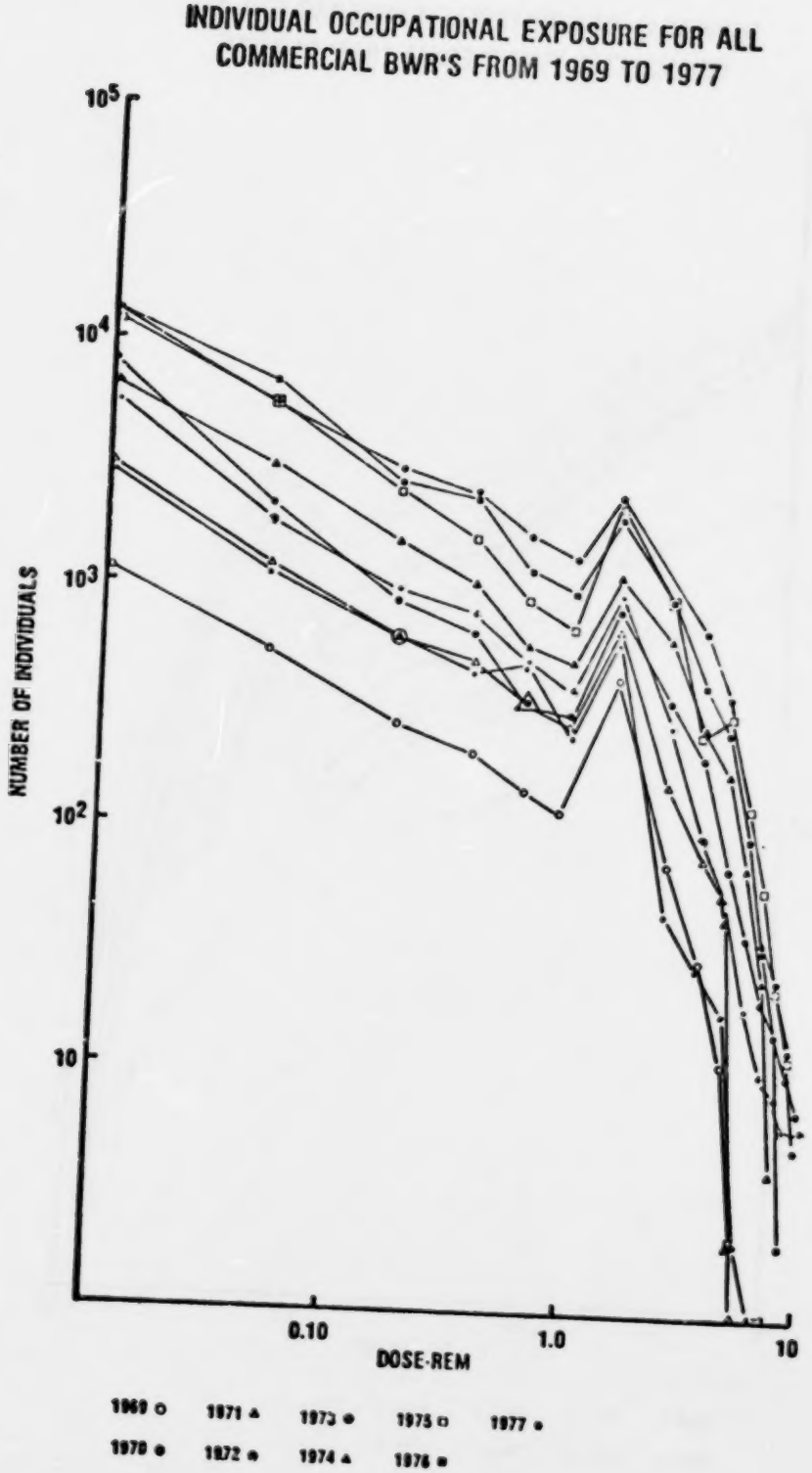

INDIVIDUAL OCCUPATIONAL EXPOSURE FOR ALL
COMMERCIAL BWR'S FROM 1969 TO 1977
10^5
10^4
10^3
10^2
10
NUMBER OF INDIVIDUALS
0.10
1.0
10
DOSE-REM
1969 ○
1970 ●
1971 ▲
1972 ●
1973 ●
1974 ▲
1975 □
1976 ●
1977 ●

FIGURE I

INDIVIDUAL OCCUPATIONAL EXPOSURE FOR ALL
COMMERCIAL PWR'S FROM 1969 TO 1977
10^5
10^4
10^3
10^2
10
NUMBER OF INDIVIDUALS
1
0.10
1.0
10
DOSE-REM
1969 ○
1971 ▲
1973 ●
1975 □
1977 ●
1970 ●
1972 ●
1974 ▲
1976 ■

FIGURE II

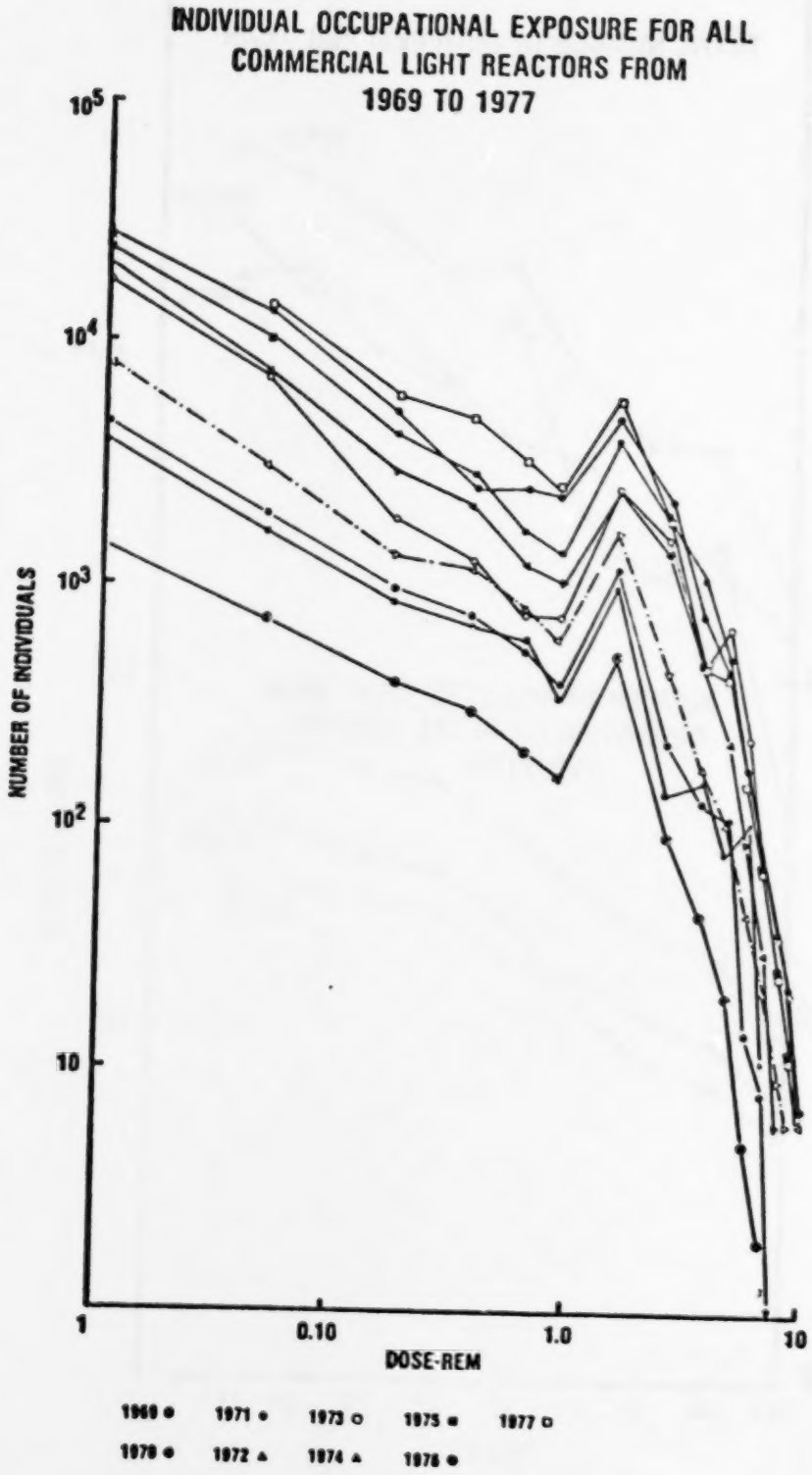

INDIVIDUAL OCCUPATIONAL EXPOSURE FOR ALL
COMMERCIAL LIGHT REACTORS FROM
1969 TO 1977
NUMBER OF INDIVIDUALS
10^5
10^4
10^3
10^2
10
1
0.10
1.0
10
DOSE-REM
1969 ● 1971 ● 1973 ○ 1975 ■ 1977 □
1970 ● 1972 ▲ 1974 ▲ 1976 ●

FIGURE III

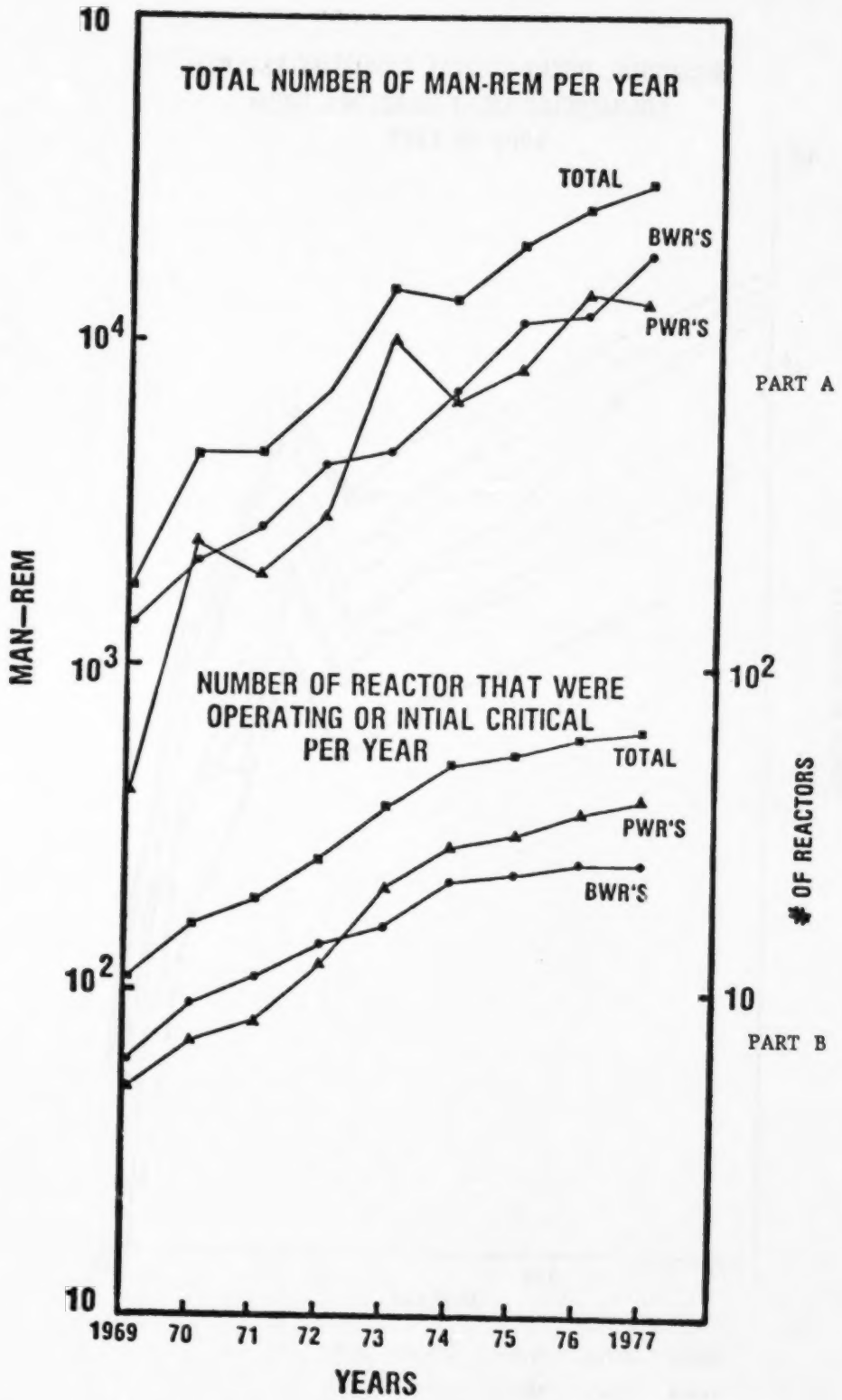

TOTAL NUMBER OF MAN-REM PER YEAR
TOTAL
BWR'S
PWR'S
MAN—REM
10^4
10^3
10^2
10
PART A
NUMBER OF REACTOR THAT WERE OPERATING OR INTIAL CRITICAL PER YEAR
TOTAL
PWR'S
BWR'S
10^2
10
OF REACTORS
PART B
1969
70
71
72
73
74
75
76
1977
YEARS

FIGURE IV

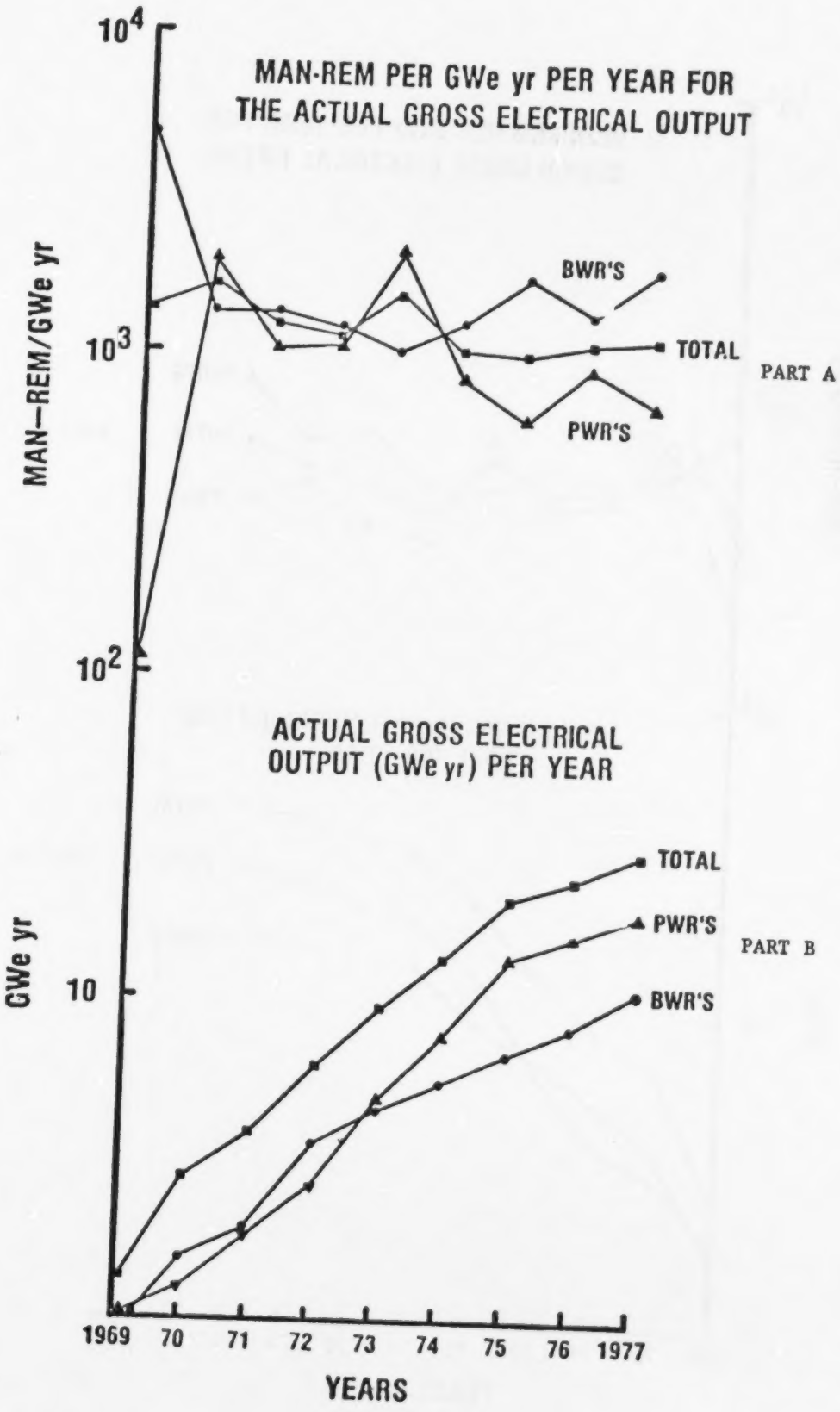

MAN-REM PER GWe yr PER YEAR FOR
THE ACTUAL GROSS ELECTRICAL OUTPUT
MAN—REM/GWe yr
10^4
10^3
10^2
BWR'S
TOTAL
PWR'S
PART A
ACTUAL GROSS ELECTRICAL
OUTPUT (GWe yr) PER YEAR
GWe yr
10
TOTAL
PWR'S
BWR'S
PART B
1969
70
71
72
73
74
75
76
1977
YEARS

FIGURE V

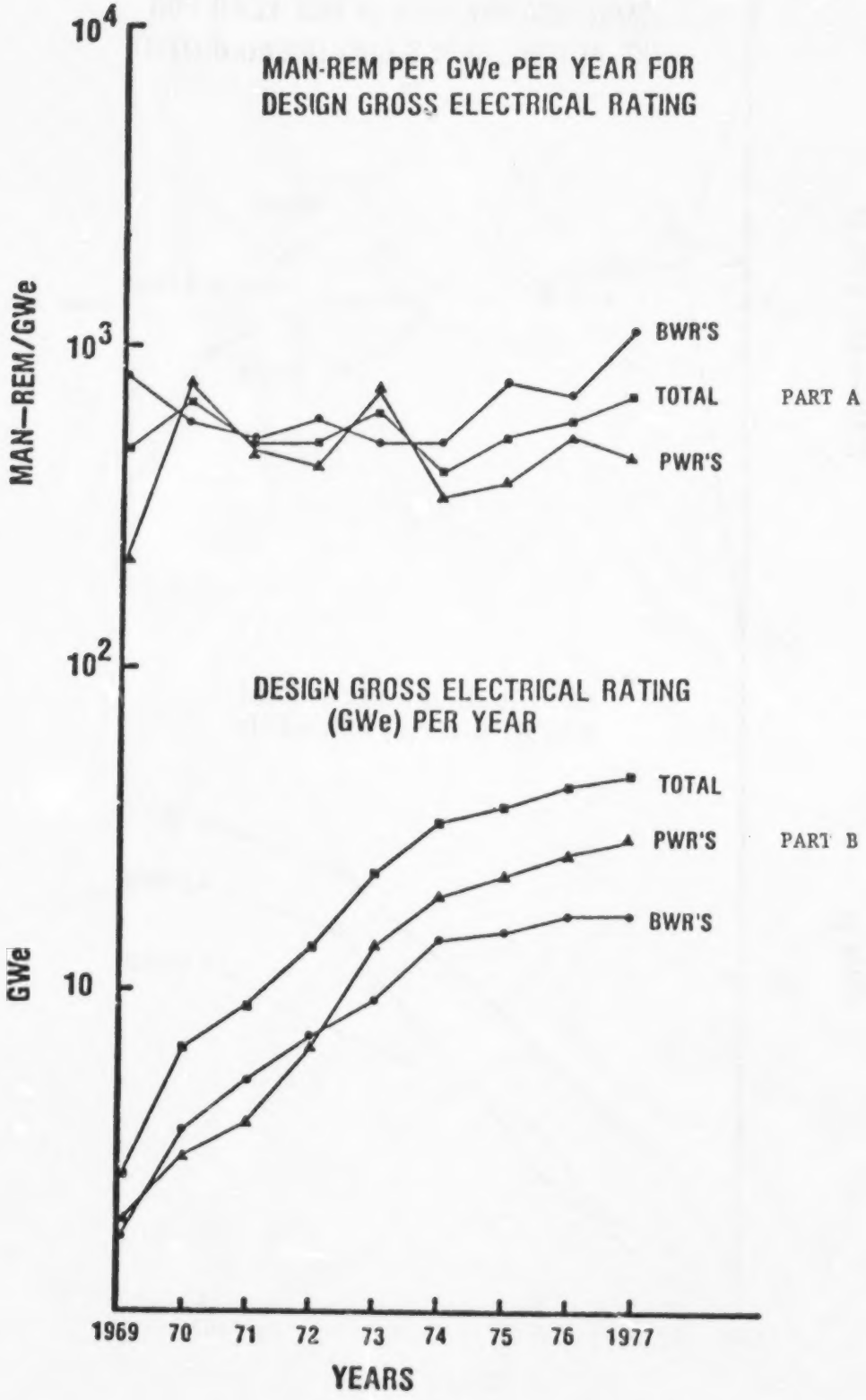

MAN-REM PER GWe PER YEAR FOR
DESIGN GROSS ELECTRICAL RATING
MAN—REM/GWe
10^4
10^3
10^2
BWR'S
TOTAL
PWR'S
PART A
DESIGN GROSS ELECTRICAL RATING
(GWe) PER YEAR
GWe
10
TOTAL
PWR'S
BWR'S
PART B
1969
70
71
72
73
74
75
76
1977
YEARS

FIGURE VI

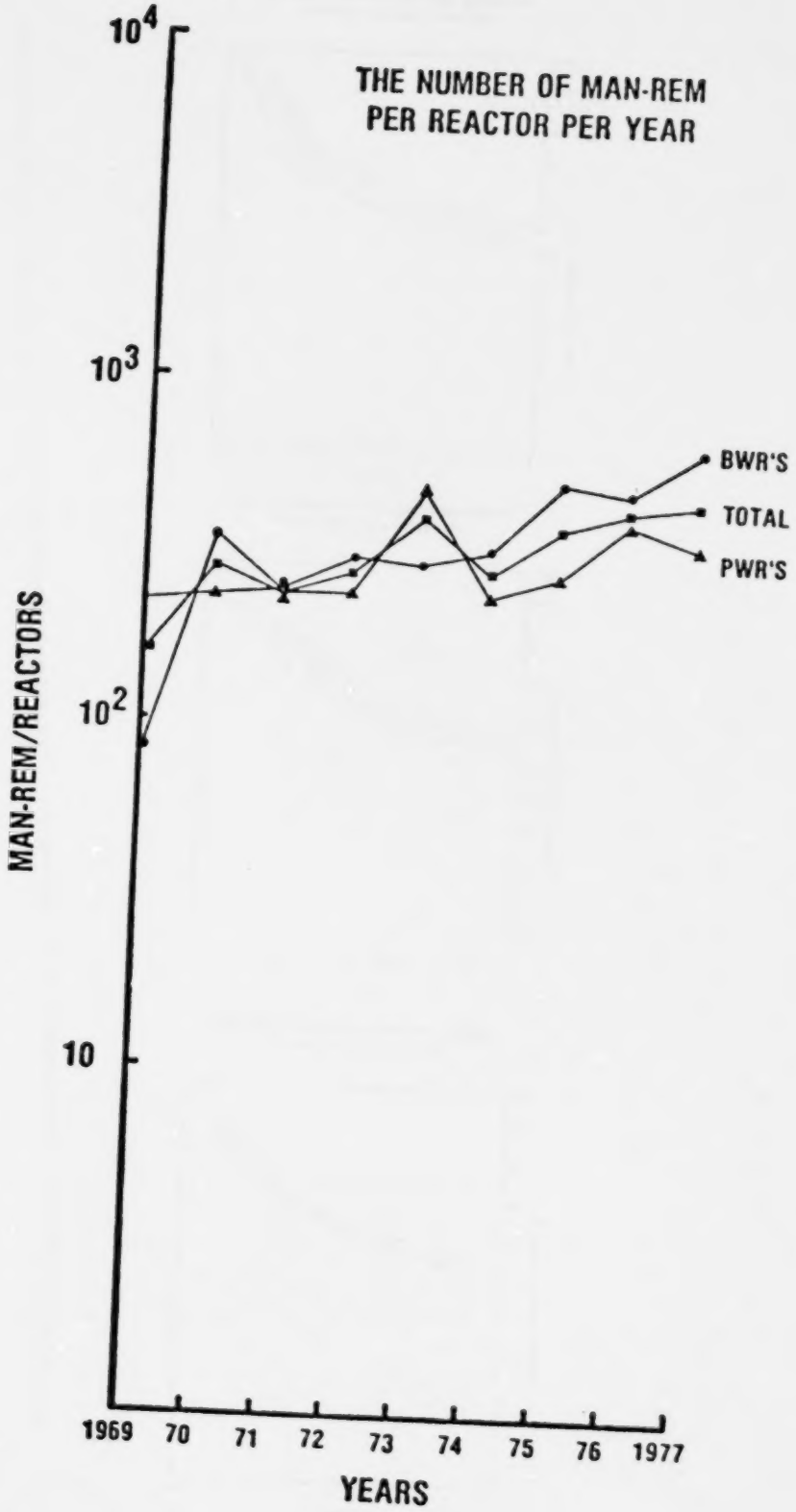
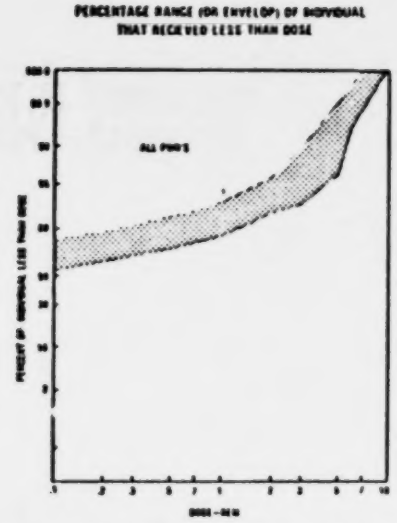
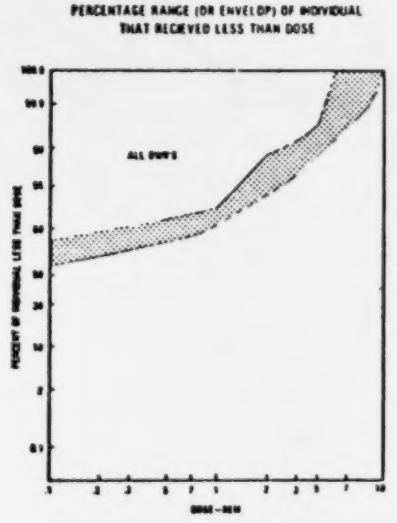

THE NUMBER OF MAN-REM
PER REACTOR PER YEAR
10^4
10^3
10^2
10
MAN-REM/REACTORS
BWR'S
TOTAL
PWR'S
1969
70
71
72
73
74
75
76
1977
YEARS

FIGURE VII


PERCENTAGE RANGE (OR ENVELOP) OF INDIVIDUAL
THAT RECEIVED LESS THAN DOSE


PERCENTAGE RANGE (OR ENVELOP) OF INDIVIDUAL
THAT RECEIVED LESS THAN DOSE

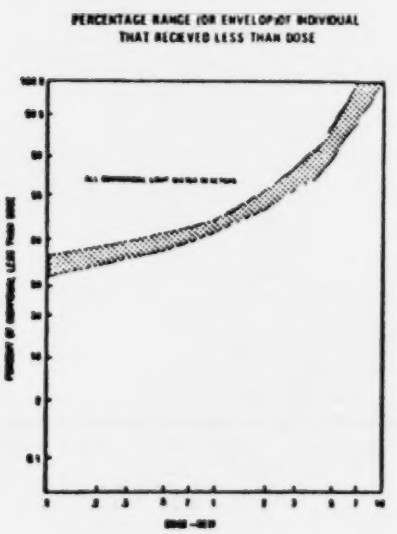

PERCENTAGE RANGE (OR ENVELOP)OF INDIVIDUAL
THAT RECEIVED LESS THAN DOSE

FIGURE VIII

PERCENTAGE RANGE (OR ENVELOP) OF INDIVIDUAL THAT RECIEVED LESS THAN DOSE

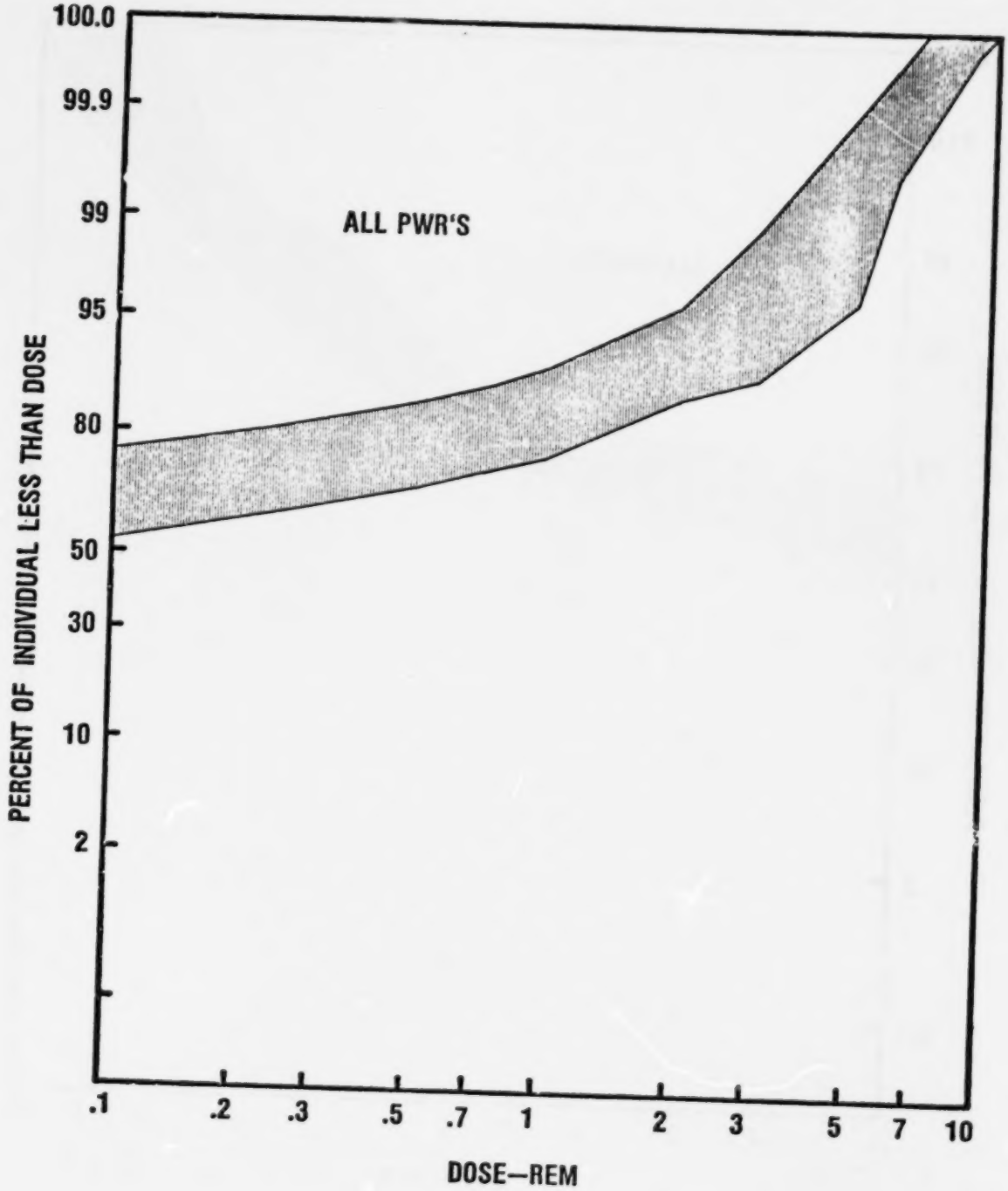


FIGURE IX

PERCENTAGE RANGE (OR ENVELOP) OF INDIVIDUAL THAT RECIEVED LESS THAN DOSE

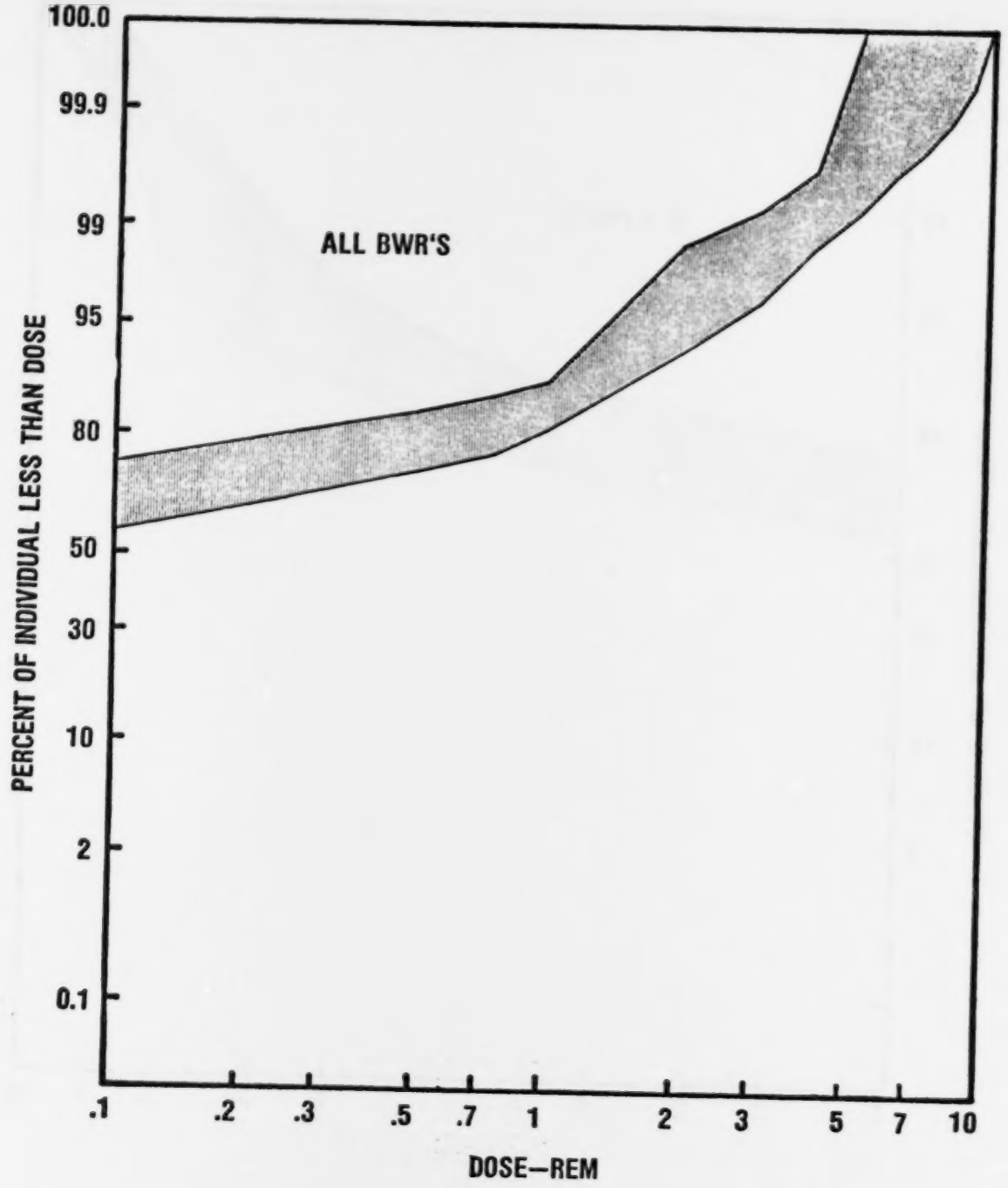


FIGURE X

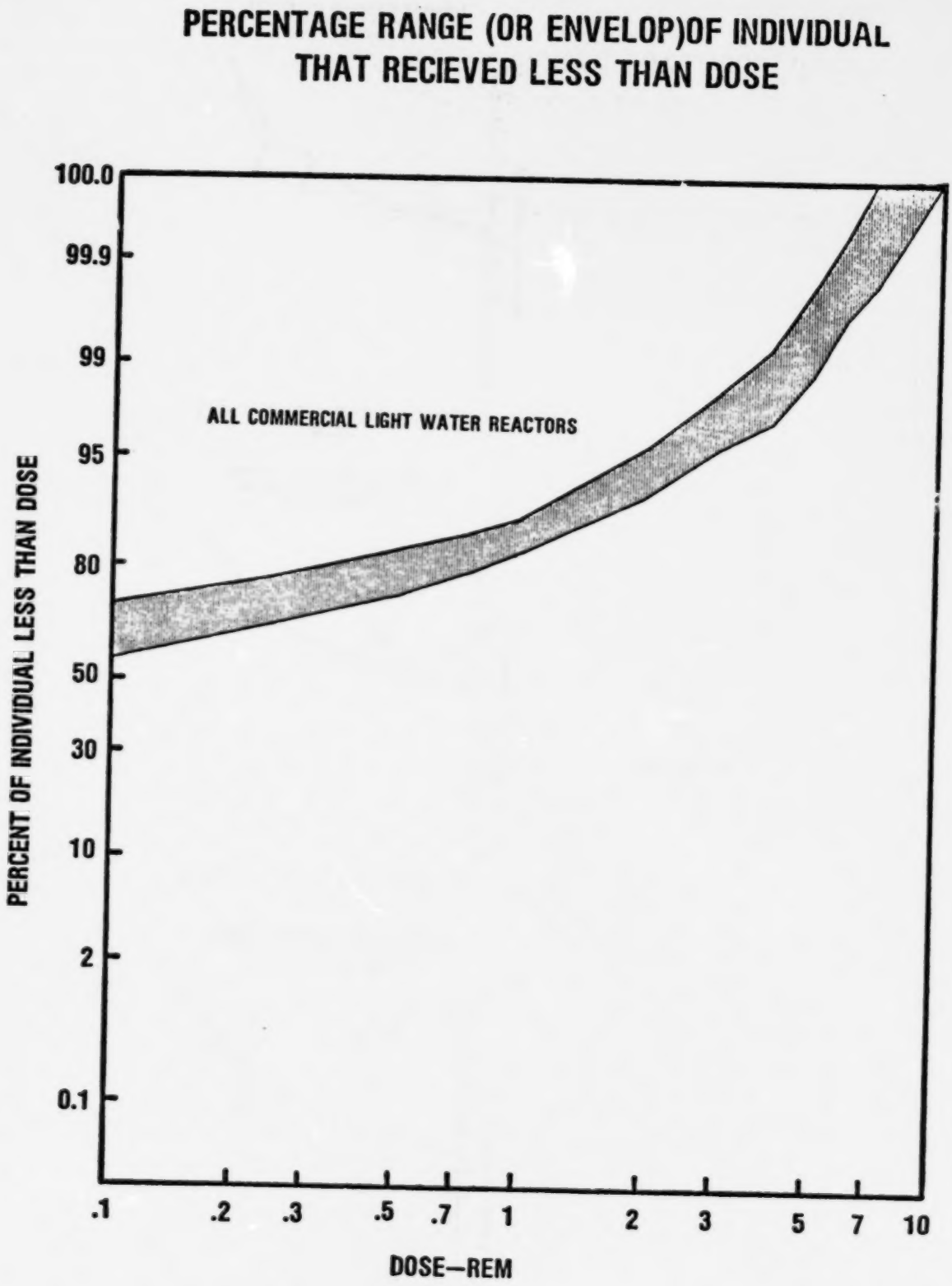
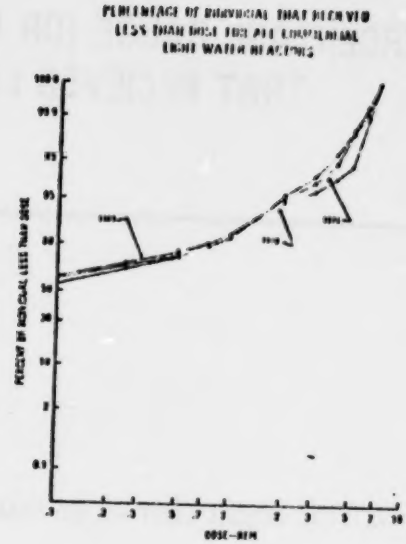

PERCENTAGE RANGE (OR ENVELOP)OF INDIVIDUAL
THAT RECIEVED LESS THAN DOSE
100.0
99.9
99
95
80
50
30
10
2
0.1
PERCENT OF INDIVIDUAL LESS THAN DOSE
ALL COMMERCIAL LIGHT WATER REACTORS
.1
.2
.3
.5
.7
1
2
3
5
7
10
DOSE—REM

FIGURE XI



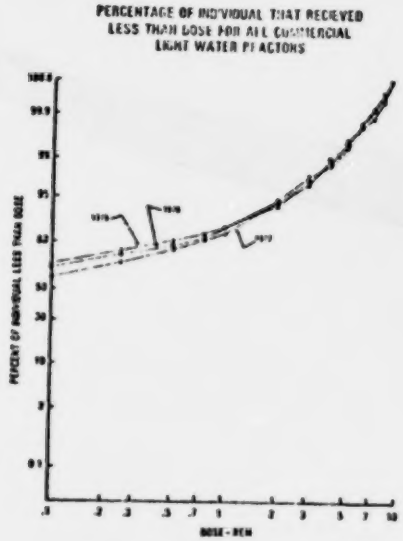
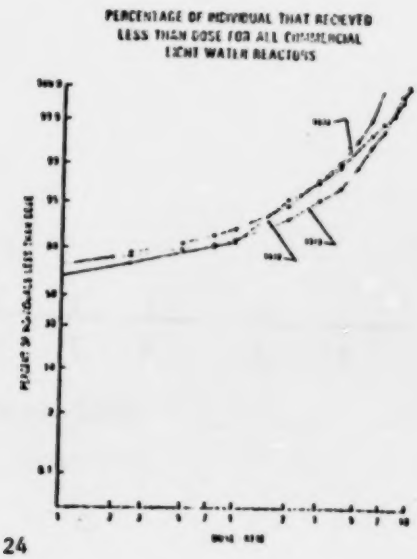


FIGURE XII



PERCENTAGE OF INDIVIDUAL THAT RECIEVED LESS THAN DOSE FOR ALL COMMERCIAL LIGHT WATER REACTORS

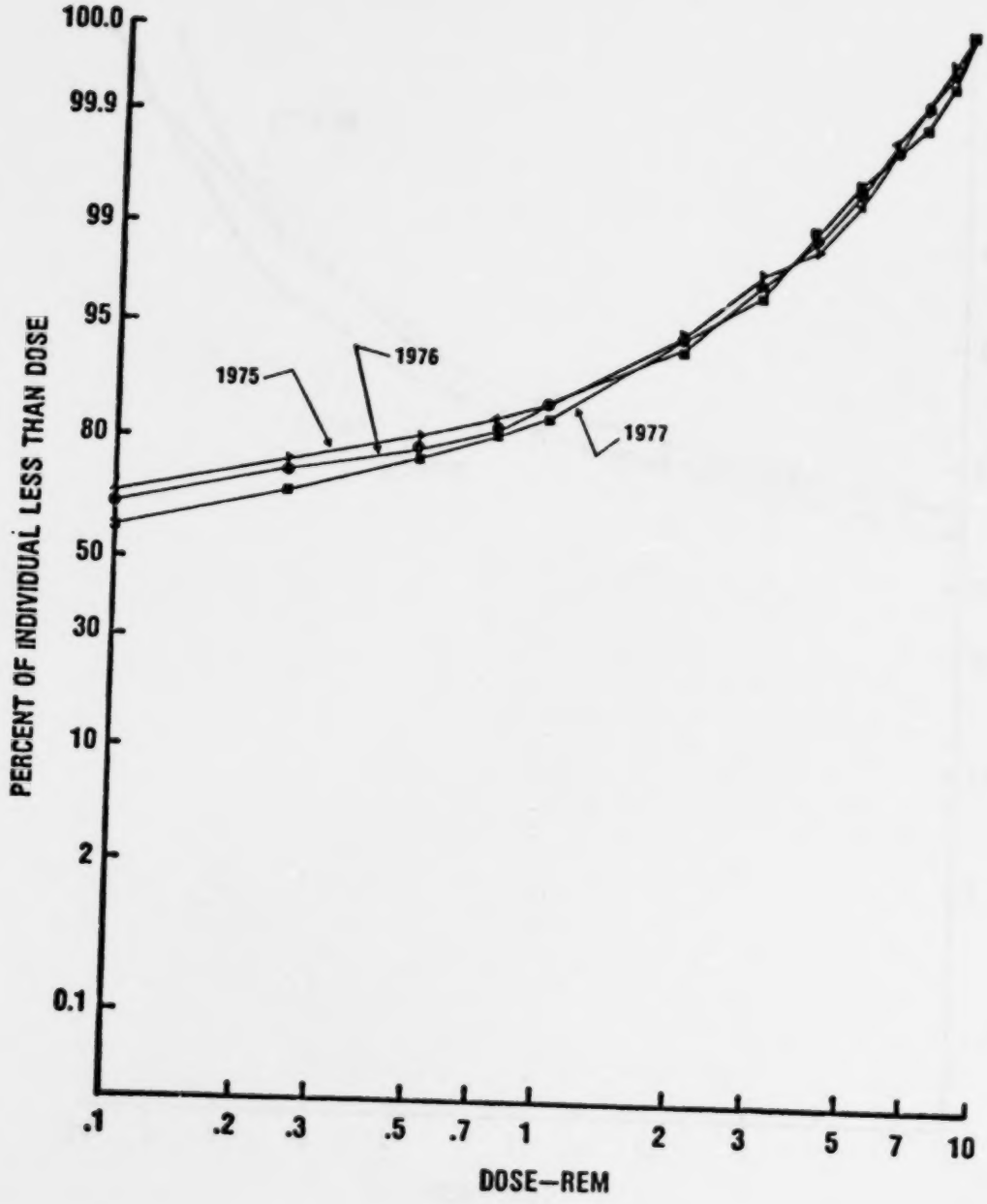


FIGURE XIII

PERCENTAGE OF INDIVIDUAL THAT RECIEVED LESS THAN DOSE FOR ALL COMMERCIAL LIGHT WATER REACTORS

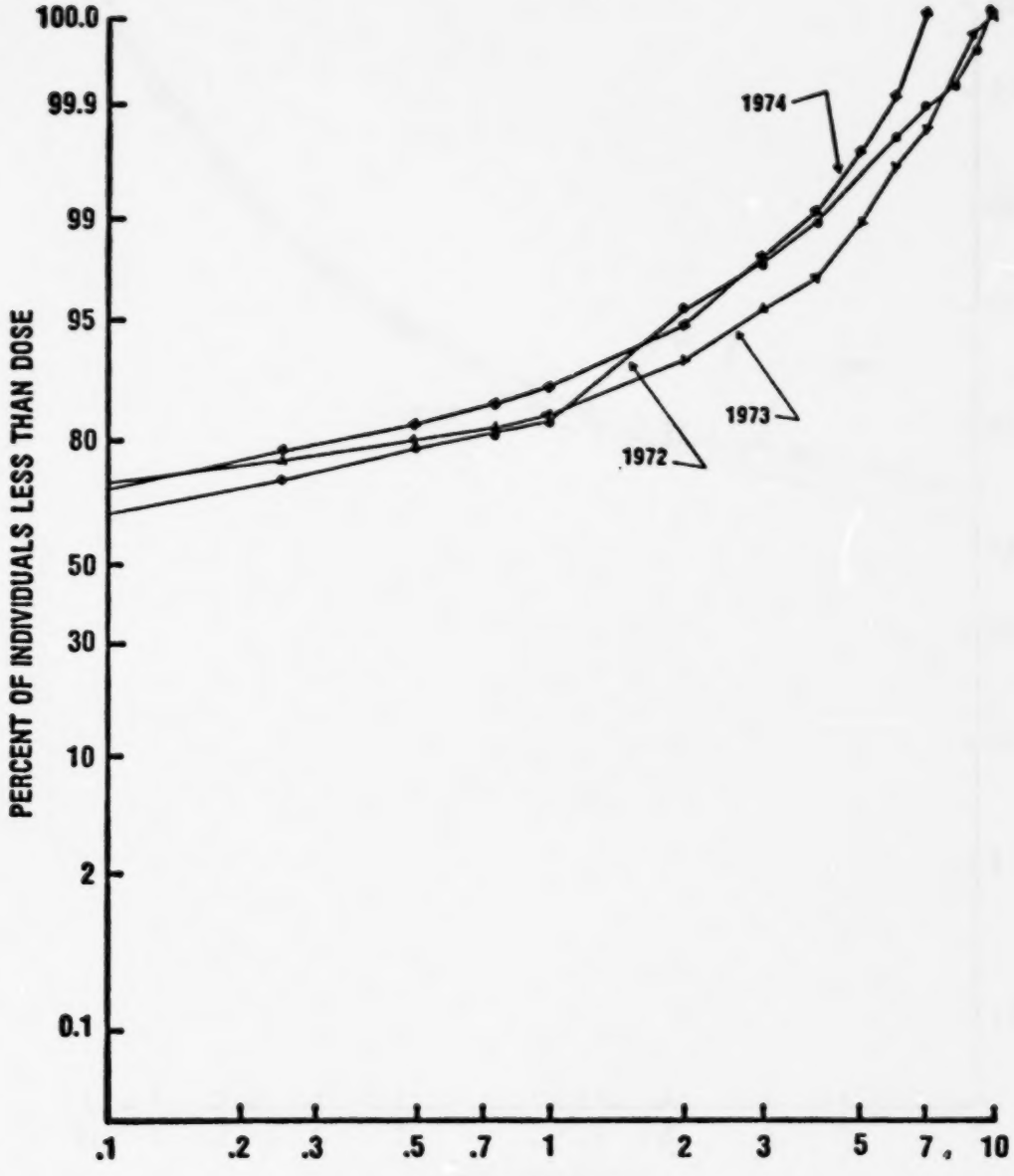


FIGURE XIV

PERCENTAGE OF INDIVIDUAL THAT RECIEVED LESS THAN DOSE FOR ALL COMMERCIAL LIGHT WATER REACTORS

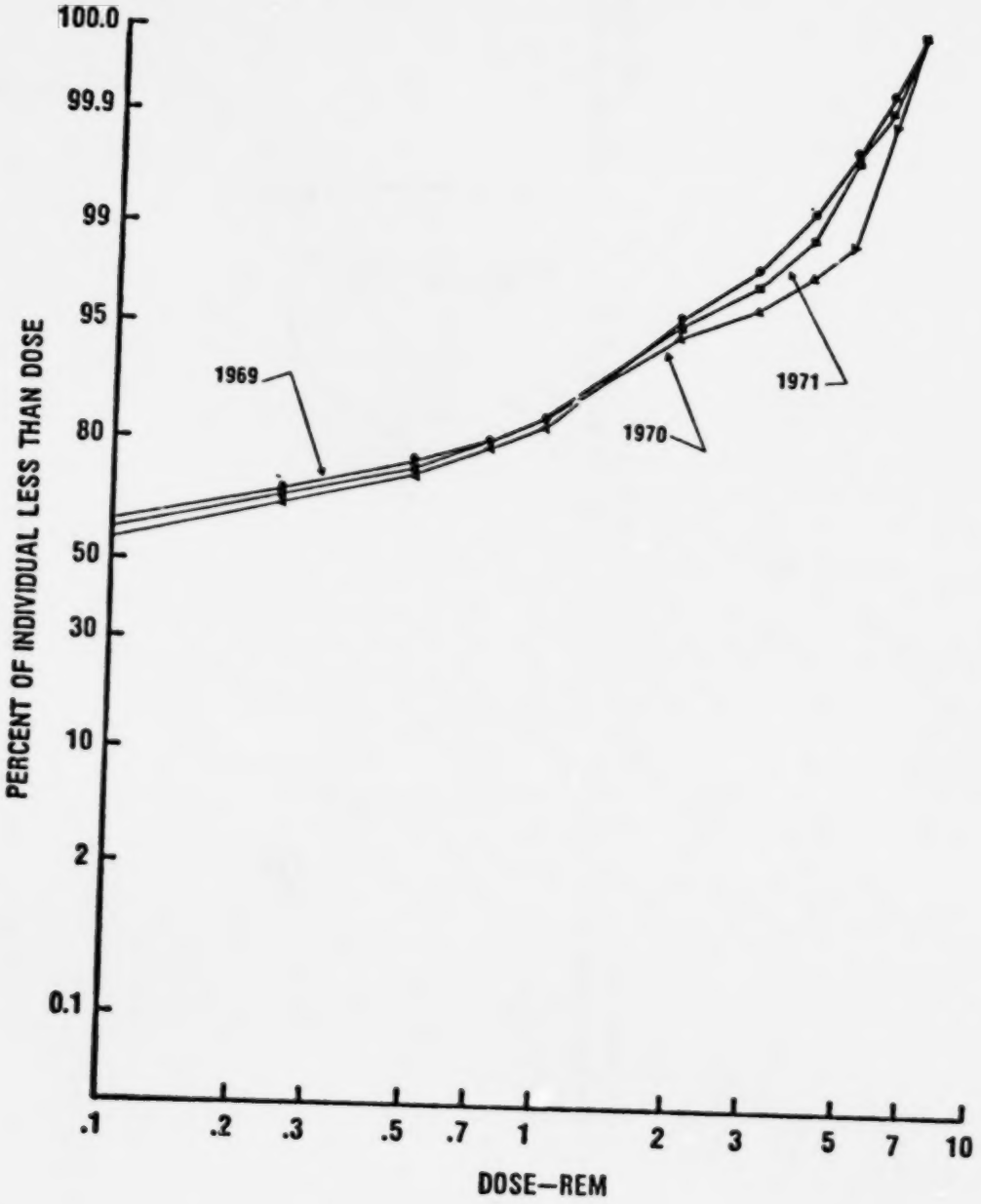
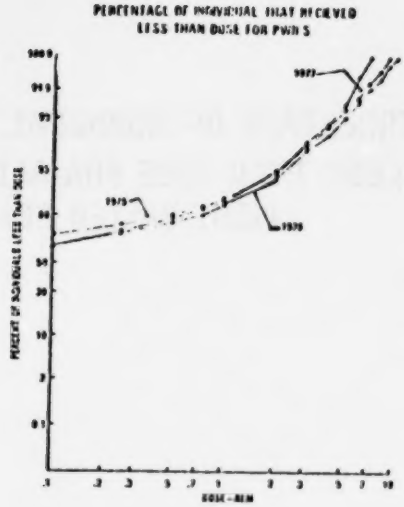


FIGURE XV


PERCENTAGE OF INDIVIDUAL THAT RECEIVED
LESS THAN DOSE FOR PWR'S

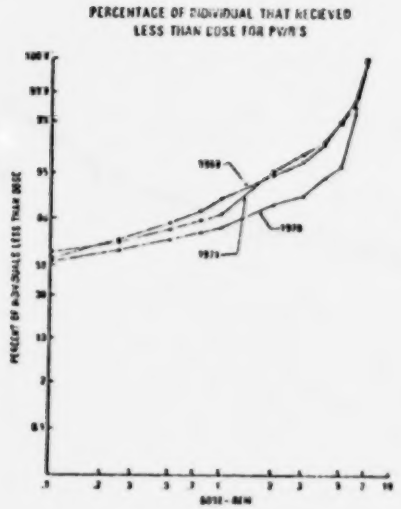
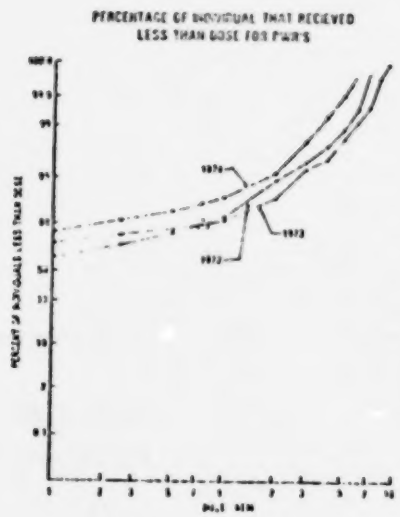

PERCENTAGE OF INDIVIDUAL THAT RECEIVED
LESS THAN DOSE FOR PWR'S

FIGURE XVI


PERCENTAGE OF INDIVIDUAL THAT RECEIVED
LESS THAN DOSE FOR PWR'S

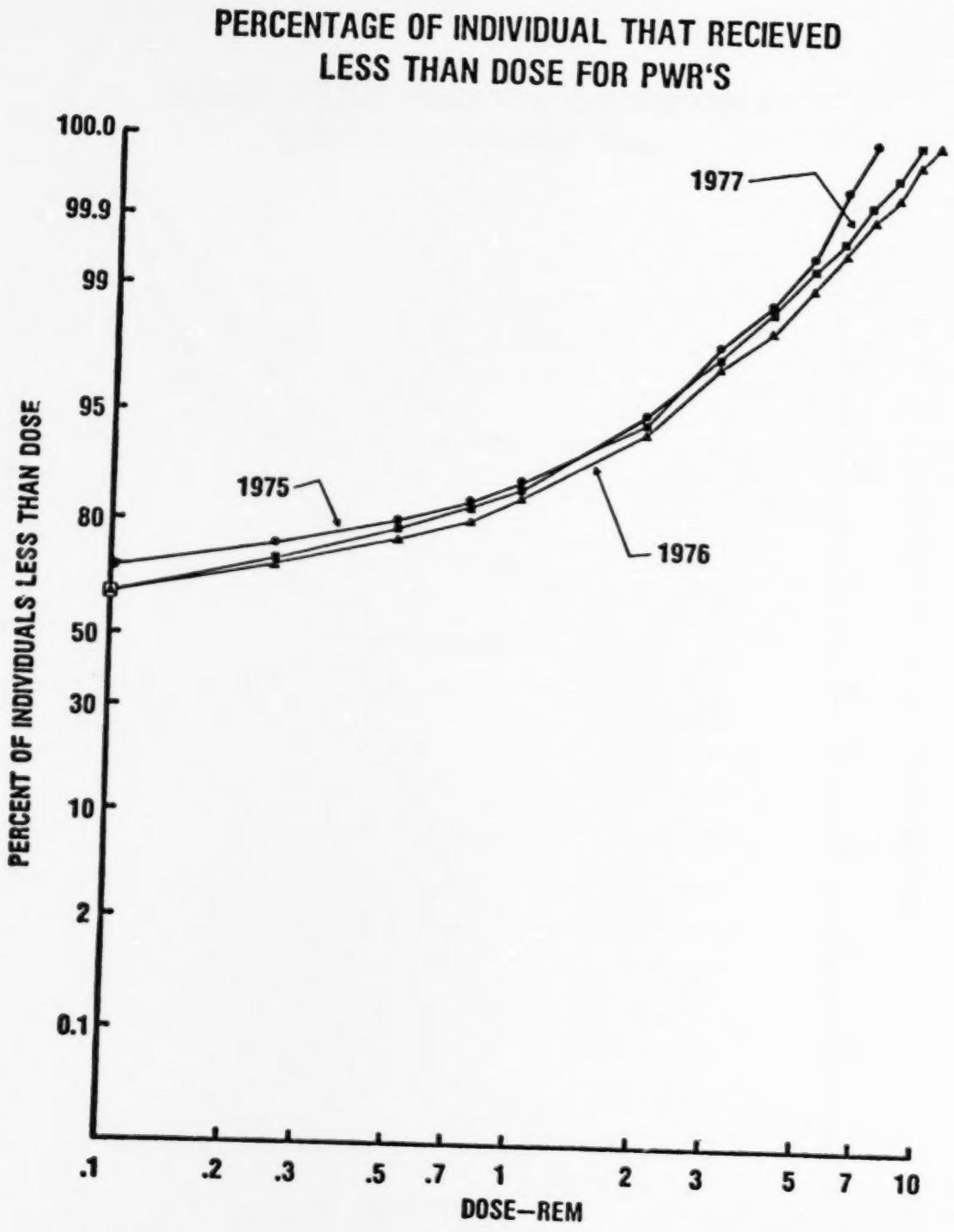

PERCENTAGE OF INDIVIDUAL THAT RECIEVED
LESS THAN DOSE FOR PWR'S
100.0
99.9
99
95
80
50
30
10
2
0.1
PERCENT OF INDIVIDUALS LESS THAN DOSE
1977
1975
1976
.1
.2
.3
.5
.7
1
2
3
5
7
10
DOSE—REM

FIGURE XVII

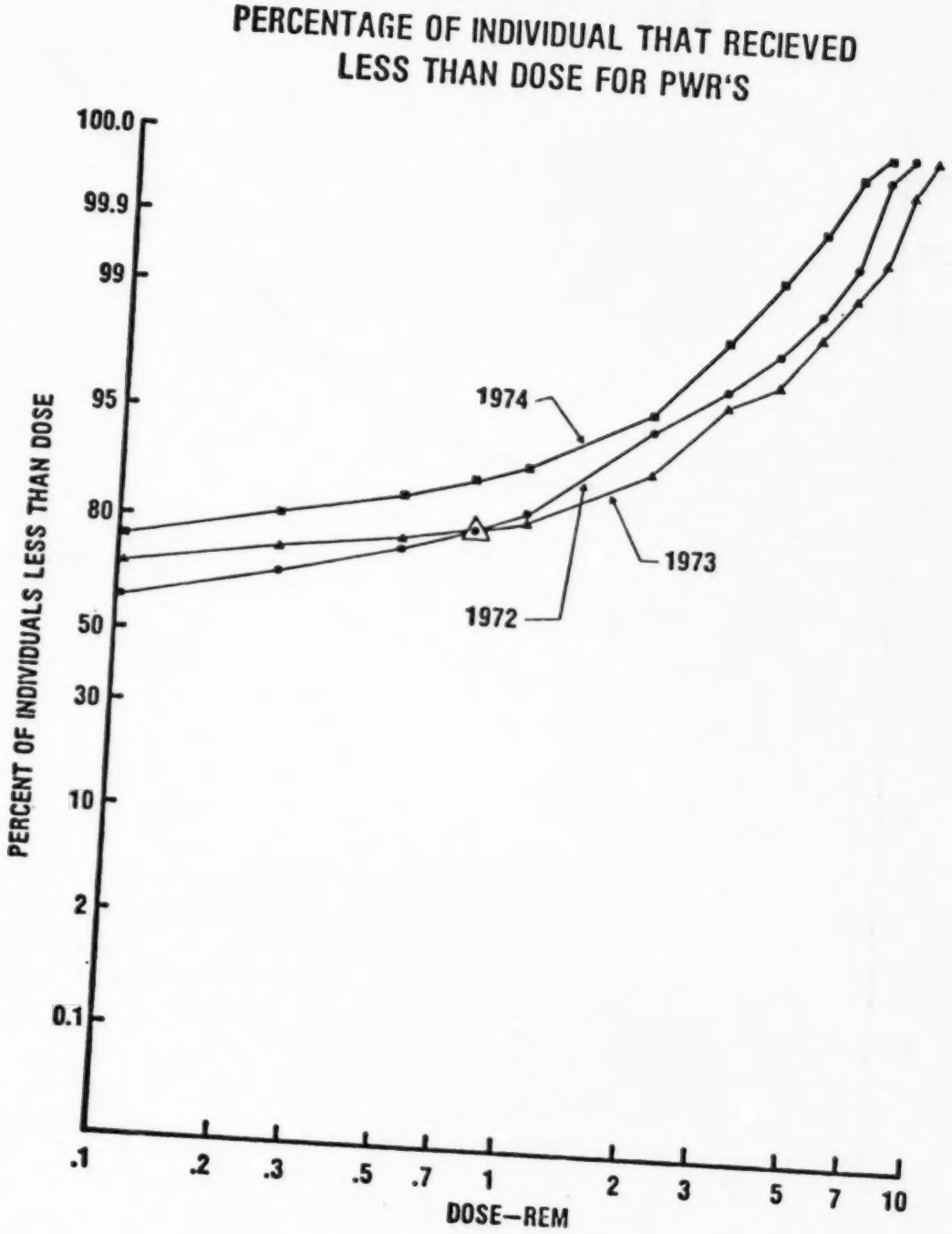


FIGURE XVIII

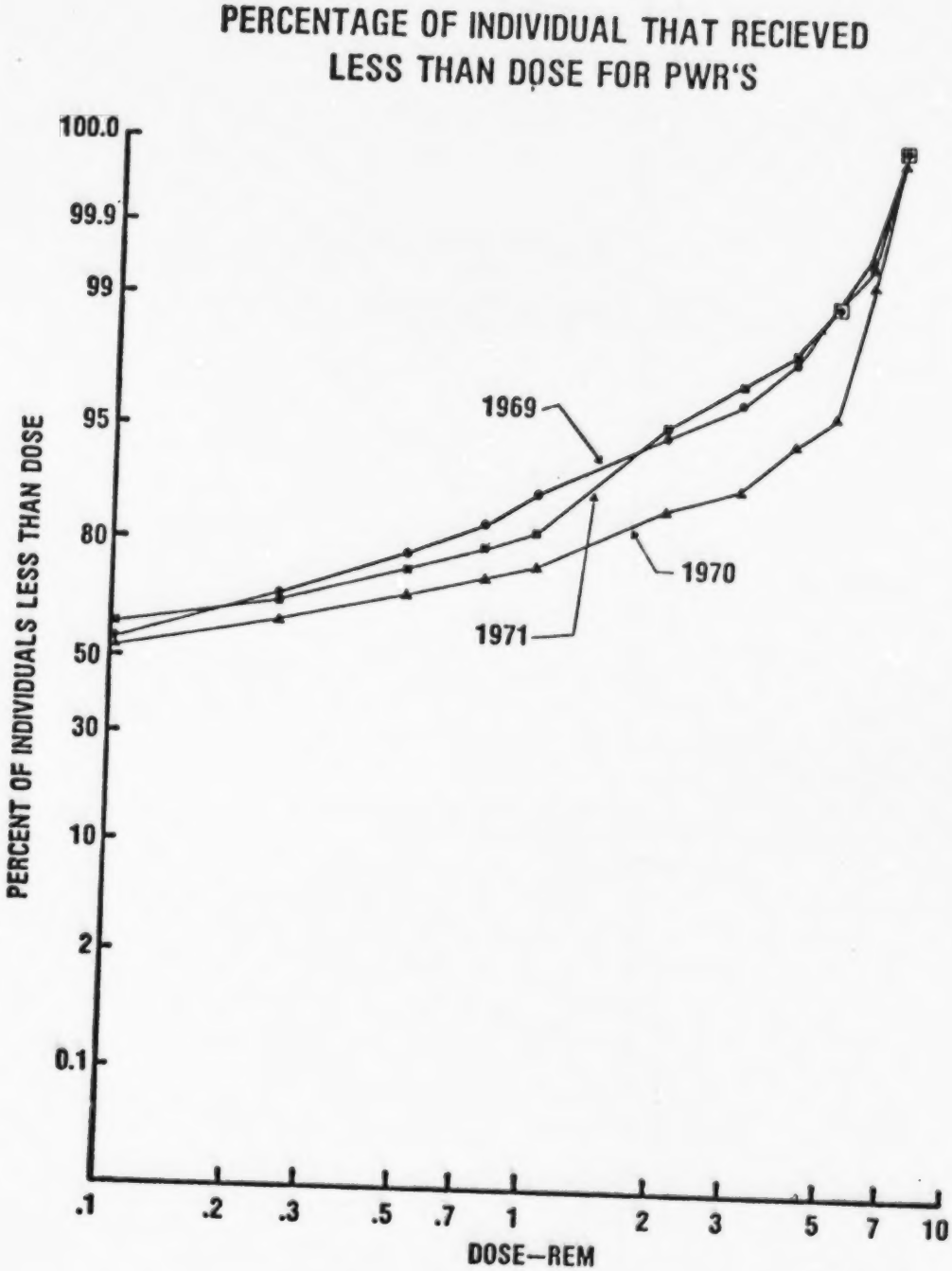
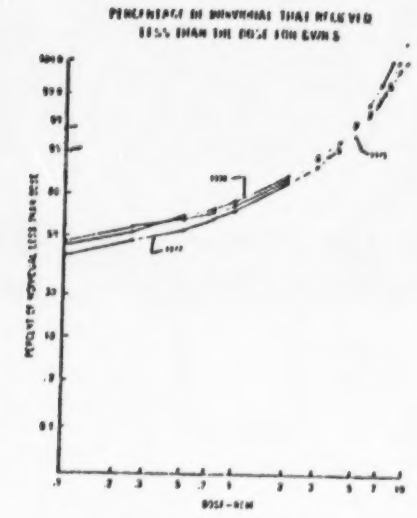

PERCENTAGE OF INDIVIDUAL THAT RECIEVED
LESS THAN DOSE FOR PWR'S
PERCENT OF INDIVIDUALS LESS THAN DOSE
100.0
99.9
99
95
80
50
30
10
2
0.1
1969
1970
1971
.1
.2
.3
.5
.7
1
2
3
5
7
10
DOSE—REM

FIGURE XIX



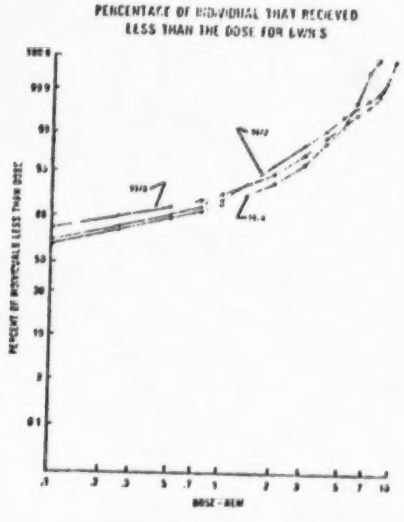
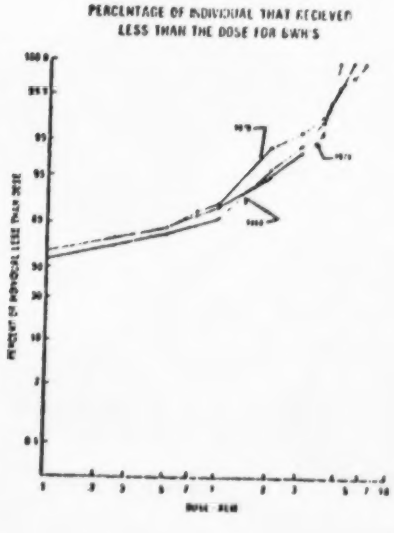


FIGURE XX



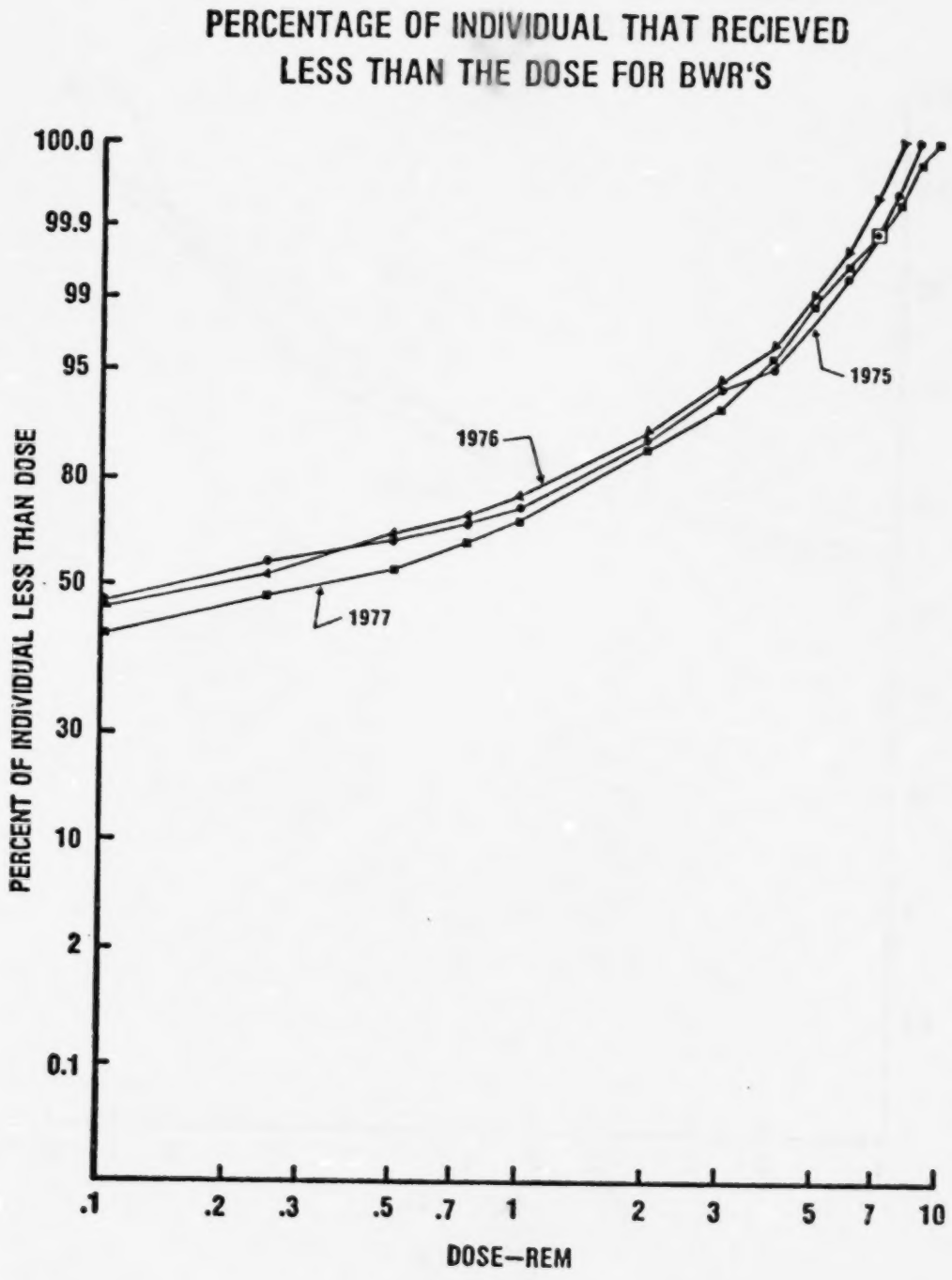

PERCENTAGE OF INDIVIDUAL THAT RECIEVED
LESS THAN THE DOSE FOR BWR'S
100.0
99.9
99
95
80
50
30
10
2
0.1
PERCENT OF INDIVIDUAL LESS THAN DOSE
1975
1976
1977
.1
.2
.3
.5
.7
1
2
3
5
7
10
DOSE—REM

FIGURE XXI

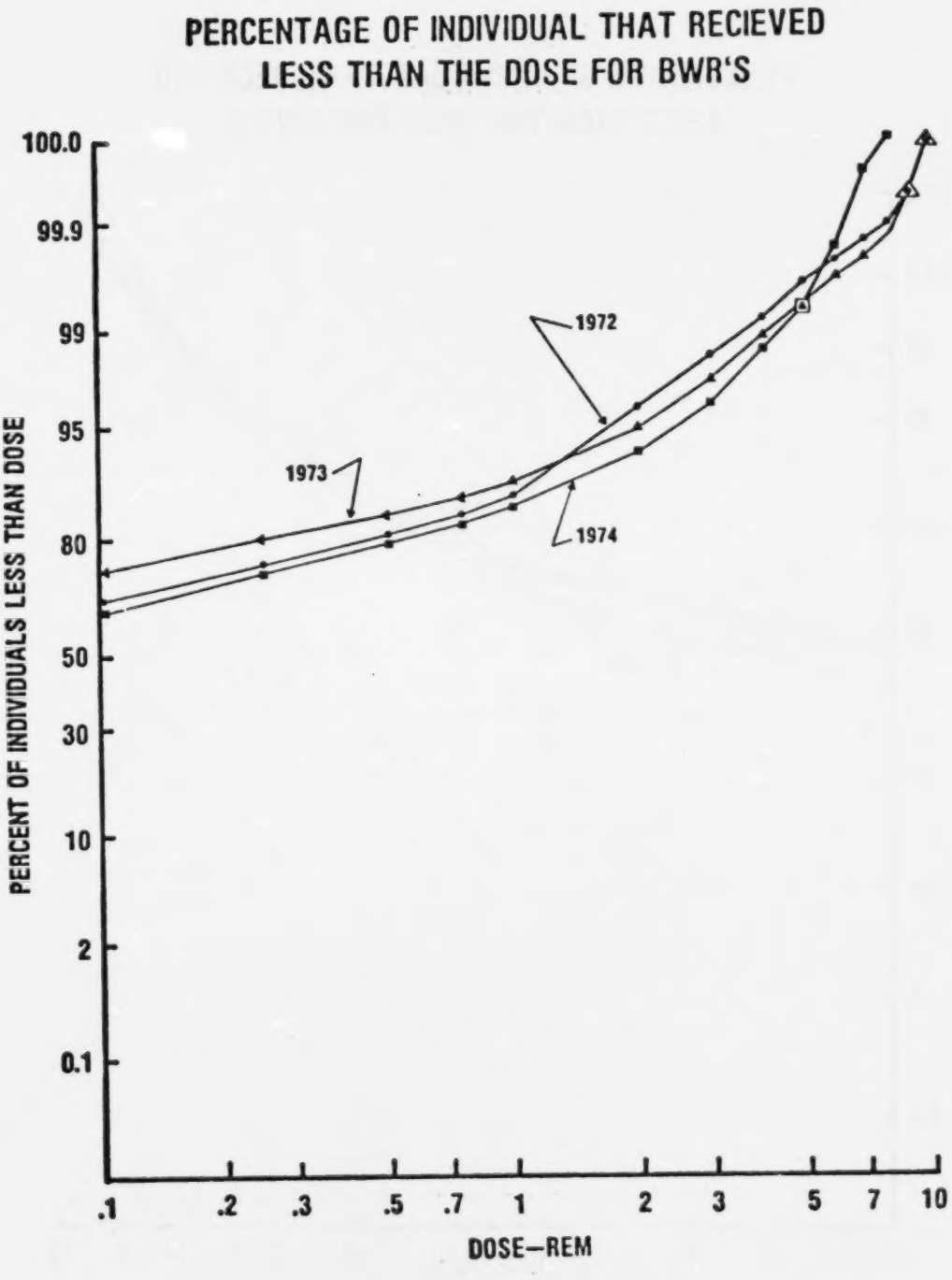

PERCENTAGE OF INDIVIDUAL THAT RECIEVED
LESS THAN THE DOSE FOR BWR'S
100.0
99.9
99
95
80
50
30
10
2
0.1
PERCENT OF INDIVIDUALS LESS THAN DOSE
1972
1973
1974
.1
.2
.3
.5
.7
1
2
3
5
7
10
DOSE—REM

FIGURE XXII

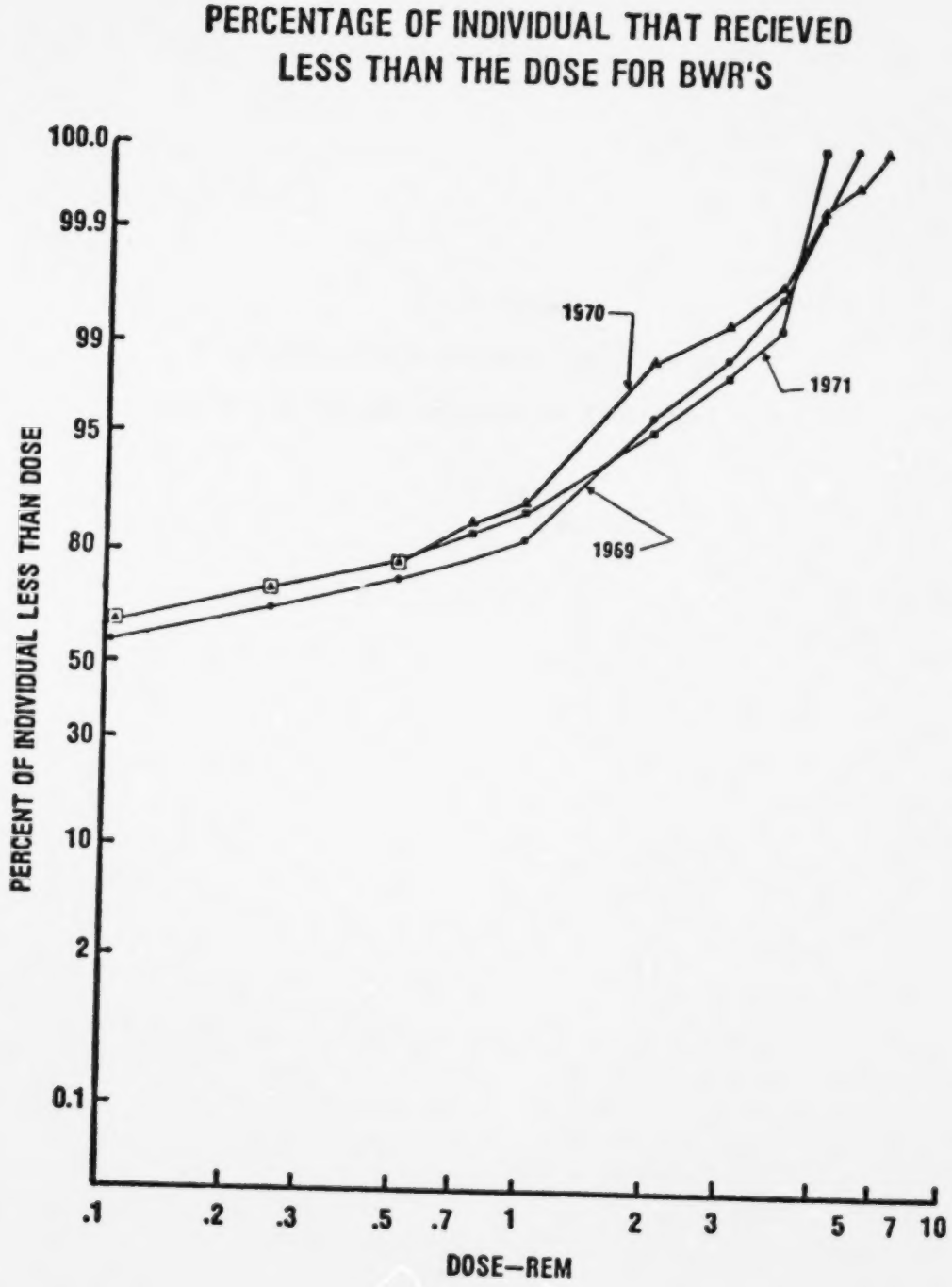


FIGURE XXIII

Appendix A

Total of All Commercial Power Reactor's

Individual Occupational Exposures Tables;

INDIVIDUAL OCCUPATIONAL EXPOSURE
BREADOWN FOR ALL COMMERCIAL PWR'S
Number Of Individuals

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	330	1084	1611	2505	10099	15028	11448	14335	
.10	209	525	767	1209	3963	4046	4918	6331	
10-.25	116	252	359	542	1004	1425	1669	2591	
25-.50	96	200	279	425	643	1111	1319	2190	
50-.75	58	132	203	302	431	636	880	1317	
75-1.0	43	95	141	215	436	535	713	1450	1206
1.0-2.0	64	328	506	723	1711	1351	1707	2809	2697
2.0-3.0	20	95	67	169	1249	734	906	1344	1055
3.0-4.0	15	131	51	84	225	198	191	346	413
4.0-5.0	9	64	48	45	168	51	103	182	141
5.0-6.0	3	100	13	24	198	15	43	89	45
6.0-7.0	2	10	8	11	46	5	8	36	29
7.0-8.0				1	24	2	1	10	12
8.0-9.0					6			9	8
9.0-10.0								5	1
10.0+								1	
Man-Rem Totals	409 / 965	2402 / 3016	1901 / 4053	2906 / 6255	10117 / 20203	6648 / 25137	8460 / 23946	14220 / 33045	13513 / 34072

INDIVIDUAL OCCUPATIONAL EXPOSURE
BREAKDAN FOR ALL COMMERCIAL LIGHT WATER REACTORS
Number Of Individuals

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	1481	3963	4651	8470	18263	21861	24535	27487	25052
.10	722	1656	1924	3054	7104	7187	10493	13293	13610
10-.25	387	855	965	1311	1878	2938	4196	5202	6199
25-.50	300	657	750	1193	1286	2161	2925	2513	4875
50-.75	204	599	525	798	762	1215	1707	2524	3247
75-1.0	161	344	399	590	730	1022	1383	2368	2520
1.0-2.0	495	966	1161	1691	2536	2466	3976	4848	6059
2.0-3.0	93	142	223	442	1592	1376	1828	2252	1878
3.0-4.0	44	158	129	179	426	470	446	747	1099
4.0-5.0	20	82	101	99	666	226	410	449	500
5.0-6.0	5	102	14	43	23[illegible]	86	171	183	140
6.0-7.0	2	11	8	21	66	30	66	69	66
7.0-8.0		1		9	39	6	24	25	36
8.0-9.0				6	16		12	11	21
9.0-10.0				6	7		0	5	6
10.0+							1	1	
Man-Rem	1744	4520	4558	7139	14805	13852	20260	26248	32554
Total	3914	9509	10850	17912	35606	41044	52173	61977	65306

INDIVIDUAL OCCUPATIONAL EXPOSURE
BREAKDOWN FOR ALL COMMERCIAL BWR'S

Number Of Individuals

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	1151	2852	3040	5965	8164	6833	13047	13152	12776
.10	513	1131	1157	1845	2195	3141	5575	6962	5582
10-.25	271	603	606	952	874	1513	2527	2611	3028
25-.50	204	457	471	768	643	1050	1606	2323	2453
50-.75	146	467	322	496	331	579	887	1207	1687
75-1.0	118	249	158	375	294	487	670	918	1314
1.0-2.0	431	638	655	968	825	1115	2269	2039	3362
2.0-3.0	73	47	156	273	343	642	917	908	823
3.0-4.0	29	27	78	95	201	272	255	401	686
4.0-5.0	11	18	53	54	72	175	307	267	359
5.0-6.0	2	2	1	19	37	71	128	94	95
6.0-7.0		1		10	20	25	58	33	37
7.0-8.0		1		8	15	4	23	15	24
8.0-9.0				6	10		12	2	13
9.0-10.0				6	7		0		5
10.0+							1		
Man-Rem	1335	2118	2657	4233	4688	7204	11800	12028	19041
Total	2949	6493	6797	11840	14031	15907	28282	30932	32244

Appendix B

Summary Tables of Data for All Commercial Light Water Reactors:

BOILING WATER REACTORS

Years	Total Man-Rem	# Of Reactors #	# Of Reactors MR/Reactor	Installed Capacity GWe	Installed Capacity MR/GWe	Electrical Out Put GW-YRe	Electrical Out Put MR/GW-YRe
1969	1335.0	6	222.5	1.645	811.55	0.29	4603.4
1970	2118.2	9	235.4	3.644	581.28	1.54	1375.5
1971	2657.0	11	241.5	5.227	508.32	1.92	1385.7
1972	4232.5	14	302.3	7.185	589.07	3.52	1202.3
1973	4688.0	16	293.0	9.315	503.27	4.50	1041.8
1974	7203.6	22	327.4	14.368	501.36	5.57	1293.3
1975	1179.9	23	513.0	15.189	776.87	6.80	1735.3
1976	12028.3	25	481.1	17.075	704.44	8.23	1461.5
1977	19040.7	25	761.6	17.075	1115.12	10.09	1887.1

MR=MAN-REM

PRESSURIZED WATER REACTORS

Years	total Man-Rem	# Of Reactors		Installed Capasity		Electrical Out Put	
		#	MR/Reactor	GWe	MR/GWe	GW-YRe	MR/GW—YRe
1969	409.1	5	81.8	1.935	211.42	0.99	413.2
1970	2402.0	7	343.1	3.132	766.92	1.25	1921.6
1971	1900.6	8	237.6	3.937	482.75	1.81	1050.1
1972	2906.1	12	242.2	6.739	431.24	2.65	1096.6
1973	10117.4	21	481.8	13.968	724.33	4.94	2048.1
1974	6647.9	28	238.4	19.352	343.53	7.77	855.6
1975	8460.0	31	272.9	22.366	378.25	13.40	631.3
1976	14219.6	36	395.0	26.828	530.03	15.59	912.1
1977	13513.0	39	346.5	29.388	459.81	18.73	721.5

MR=MAN-REM

ALL LIGHT WATER REACTORS

Years	Total Man-Rem	# Of Reactors		Installed Capacity		Electrical Out Put	
		#	MR/Reactor	GWe	MR/GWe	GW-YRe	MR/GW-YRe
1969	1744.2	11	158.6	3.58	487.21	1.28	1362.7
1970	4520.2	16	282.5	6.776	667.09	2.79	1620.1
1971	4557.6	19	239.9	9.164	497.34	3.73	1221.9
1972	7138.6	26	274.6	13.924	512.68	6.17	1157.0
1973	14805.4	37	400.1	23.283	635.89	9.44	1568.4
1974	13851.5	50	277.0	33.72	410.78	13.34	1038.3
1975	20259.9	54	375.2	37.555	539.47	20.20	1003.0
1976	26247.9	61	430.3	43.903	597.86	23.82	1101.9
1977	32553.7	64	508.7	46.463	700.64	28.82	1129.6

MR=MAN-REM

Appendix C

Percentage Tables of Individuals that

Recieved Less than Dose;

THE PERCENTAGE OF INDIVIDUAL
THAT RECIEVED LEST THAN DOSE
FOR THE YEARS 1969-1977 FOR THE BWR'S

PERCENT OF INDIVIUALS

Dose-Rem	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	39.03	43.92	44.73	50.38	58.19	42.96	46.13	42.52	39.62
.10	56.43	61.34	61.75	65.96	73.83	62.70	65.84	65.03	56.93
.25	65.62	70.63	70.66	74.00	80.06	72.21	74.78	73.47	66.33
.50	72.53	77.67	77.59	80.49	84.64	78.81	80.46	80.98	73.93
.75	77.48	84.86	82.23	84.68	87.00	82.45	83.59	84.88	79.17
1.0	81.49	88.70	86.13	87.85	89.10	85.52	85.96	87.85	83.24
2.0	96.10	98.52	95.76	96.02	94.98	92.53	93.99	94.44	93.67
3.0	98.58	99.25	98.06	98.33	97.42	96.56	97.23	97.37	96.22
4.0	99.56	99.66	99.21	99.13	98.85	98.27	98.13	98.67	98.35
5.0	99.93	99.94	99.99	99.59	99.37	99.37	99.22	99.53	99.46
6.0	100	99.97	100	99.75	99.63	99.82	99.67	99.84	99.75
7.0		99.99		99.83	99.77	99.77	99.87	99.95	99.87
8.0		100		99.89	99.88	100	99.95	99.99	99.94
9.0				99.95	99.95		99.99	100	99.98
10.0				100	100		99.99		100
10.0-+							100		

THE PERCENTAGE OF INDIVIDUAL
THAT RECIEVED LEST THAN DOSE
FOR THE YEARS 1969-1977 FOR THE LIGHT WATER REACTORS

PERCENT OF INDIVIDUALS

Dose-Rem	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	37.84	41.39	42.86	47.29	51.29	53.33	47.03	44.35	38.36
.10	56.29	58.81	60.60	64.34.	71.24	70.77	67.14	65.80	59.20
.25	66.17	67.80	69.49	71.66	76.52	77.93	75.18	74.19	68.69
.50	73.84	74.71	76.41	78.32	80.13	83.20	80.79	78.25	76.16
.75	79.05	81.01	81.24	82.77	82.27	86.16	84.06	82.32	81.13
1.0	83.16	84.63	84.92	86.01	84.32	88.65	86.71	86.14	84.99
2.0	95.81	94.78	95.62	95.51	91.44	94.47	94.33	93.96	94.26
3.0	98.19	96.28	97.68	97.97	95.91	98.01	97.83	97.60	97.14
4.0	99.31	97.94	98.87	98.97	97.11	99.15	98.69	98.80	98.82
5.0	99.82	98.80	99.80	99.53	98.98	99.70	99.47	99.52	99.59
6.0	99.95	99.87	99.93	99.77	99.64	99.91	99.80	99.82	99.80
7.0	100	99.99	100	99.88	99.82	99.99	99.93	99.93	99.90
8.0		100		99.93	99.94	100	99.97	99.97	99.96
9.0				99.97	99.98		99.99	99.99	99.99
10.0				100	100		99.99	99.99	100
10.0-+							100	100	

THE PERCENTAGE OF INDIVIDUAL
THAT RECIEVED LEST THAN DOSE
FOR THE YEARS 1969-1977 FOR THE PWR'S

PERCENT OF INDIVIDUALS

Dose-Rem	1969	1970	1971	1972	1973	1974	1975	1976	1977
Not Measurable	34.20	35.94	39.75	40.05	49.99	59.78	47.97	43.38	38.96
.10	55.85	58.67	59.38	69.60	75.88	68.51	62.54	62.5	62.54
.25	67.88	61.70	67.53	68.04	74.57	81.55	75.48	70.38	71.86
.50	77.82	68.34	74.41	74.84	77.76	85.97	80.99	77.01	78.97
.75	83.83	72.71	79.42	79.66	79.89	88.50	84.67	80.99	83.54
1.0	88.29	75.86	82.90	83.10	82.05	90.63	87.64	85.38	87.08
2.0	94.92	86.74	95.39	94.66	90.52	96.00	94.77	93.88	94.99
3.0	96.99	89.89	97.70	97.36	96.70	98.92	98.56	97.95	98.10
4.0	98.55	94.23	98.30	98.71	97.81	99.71	99.35	98.99	99.31
5.0	99.48	96.35	99.48	99.42	98.64	99.91	99.78	99.55	99.72
6.0	99.79	99.67	99.80	99.81	99.62	99.79	99.96	99.82	99.85
7.0	100	100	100	99.98	99.85	99.99	99.99	99.92	99.94
8.0				100	99.97	100	100	99.95	99.97
9.0					100			99.98	99.99
10.0								99.99	100
10.0- +								100	

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